JPRS 74982

23 January 1980

China Report

AGRICULTURE

No. 67

Paddy Rice Cultivation

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Correspondence pertaining to matters other than procurement may be addressed to Joint Publications Research Service, 1000 North Glebe Road, Arlington, Virginia 22201.

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. JPRS 74982

2.

3. Recipient's Accession No.

4. Title and Subtitle
CHINA REPORT: AGRICULTURE, No. 67
Paddy Rice Cultivation

5. Report Date
23 January 1980

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Joint Publications Research Service
1000 North Glebe Road
Arlington, Virginia 22201

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
As above

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This serial report contains information on agricultural activities in China.

17. Document Analysis a. Descriptors

CHINA
Agriculture
Weather
Statistics
Crops
Animal Husbandry
Forestry
Soil
Pisciculture

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group 2

18. Availability Statement
Unlimited Availability
Sold by NTIS
Springfield, Virginia 22161

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 76

22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

JPRS 74982

23 January 1980

CHINA REPORT

AGRICULTURE

No. 67

PADDY RICE CULTIVATION

Beijing SHUIDAO [PADDY RICE] in Chinese Nov 76 pp 141-209

[This book was compiled by the Agricultural Sciences Department of the Zhejiang Agricultural University and the Crop Institute of the Zhejiang Provincial Academy of Agricultural Sciences; published by the Scientific Publishing House, Beijing, November 1976. Pages 1-141A of this book were translated and published in JPRS 72999, 14 March 1979, No. 26 of this series, pp 1-151]

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[Text] CHAPTER THREE: GENETICS AND BREEDING OF PADDY RICE

I. Multiplicity of Paddy Rice Varieties and Their Formation

Many varieties of paddy rice are cultivated in our nation. The types of rice are rich and varied. Based on incomplete statistics, over 10,000 varieties have been collected in addition to those already being cultivated. Among them are xian [hsien] rice, geng [keng] rice, early, intermediate and late rice, paddy rice, dryland rice, glutinous and starchy rice.

Xian and geng rice are geoclimatic ecological types formed and differentiated under different temperature conditions. Xian rice is distributed mainly in the southern tropical zones and subtropical zones south of the Hui River. Geng rice is distributed mainly along the Taihu River areas, southern tropical and subtropical highlands and low temperature areas in northern China, the northeast and the northwest. Again, let us observe the perpendicular distribution of xian rice and geng rice in Yunnan. At an elevation of 1,750 meters and below is the xian rice zone. The zone between 1,750 meters and 2,000 meters above sea level is the mixed geng and xian rice zone. Above 2,000 meters is the geng rice zone. This proves that distribution of xian and geng rice is controlled by temperature conditions. Xian and geng rice are different in both physical and physiological characteristics. These are listed in Table 17.

Early, intermediate and late rice are mainly different seasonal and climatic ecological types differentiated under different sunlight conditions. Early rice has a short growth period. Intermediate rice has the second shortest growth period and late rice has the longest growth period. Late rice is strongly photosensitive. It is a short sunlight crop. Its panicles will differentiate, head and fruit only under short sunlight conditions. Under long sunshine periods, its panicles will not differentiate normally nor head normally. Late rice sown in the spring will not differentiate even though temperature conditions may satisfy its demands. It will wait until the end of summer and beginning of autumn when the sunlight period slowly shortens to differentiate normally. Early rice is strongly tolerant to sunlight. Whether it is exposed to long sunshine periods or short sunlight conditions, as long as its temperature conditions are satisfied, it will normally head and fruit. Intermediate rice basically is the same as early rice. Some intermediate geng rice varieties are strongly sensitive to light. Early rice, intermediate rice and late rice are all thermophytes. Under natural conditions suitable for their growth, high temperature assures fast growth and low temperatures cause slow growth. Changes during the growth period of early rice, which is poor photosensitive, are mainly determined by temperature conditions. The strongly photosensitive late rice is affected by the duration of sunlight conditions, while temperature conditions proportionately have less effect.

Table 17 Difference Between Xian and Geng Rice

Characteristics	Xian	Geng
leaf shape	wide leaf	narrow leaf
leaf color	light	dark
leaf pubescence	plenty	few or none
flag leaf angle	small	large
plant type	loose	tight
grain type	wide and long or narrow and long, oval cross section	wide and short, round cross section
awns	most without or short if any	some have long awns, others none
husk and pubescence	thin , few	thick, long and dense
speed of germinating under high temperatures	fast but grows slowly in low temperatures	slow but grows fast in low temperatures
tolerance to cold and heat	weak tolerance to cold in early period, tolerates heat in later period	tolerant to cold in early period but not tolerant to heat in later period
tillering	strong and prosperous	weak and not prosperous
tolerance to fertilizers resistance against lodging	not tolerant and easily lodges. Dwarf varieties are more tolerant and do not easily lodge	generally tolerant to fertilizers and do not easily lodge
resistance to disease	strongly resistant to blast weak resistance to white leaf wilt	weak resistance to blast strongly resistant to white leaf wilt
shattering	grains easily shatter, except for a few varieties	grains do not easily shatter except for a few varieties
quality of rice	low yield, poor glutinosity, expansive, plenty of loose rice	high yield, less loose rice, strong glutinosity, less expansive

Paddy rice and upland rice are different mainly because they are differentiated under different soil and moisture conditions into two soil ecological types. In general, upland rice has a more developed root with a lot of root hairs. The stems are thick and strong. The leaves are large and wide. The color of the leaves is light. The protective tissues of the leaves on the stem are developed. It is heat and drought tolerant. It is suitable for planting on slopes and drylands. Its grain hull is thick and yield is low. It yields a lot of loose rice grains, the quality of the rice is poor and its production is low. Therefore, its cultivation area is limited. Of course, there are also drought tolerant varieties of paddy rice. There is also deep water paddy rice which can grow in deep water. Its tolerance of water and rooting strength are strong and its stems can extend upward with the rise of the water level. After the water recedes, the rice plant grows upward. Floating paddy rice has a stronger ability to extend its stems to the surface of the water along with the rising water level, but when the water level recedes, the rice grows like vines.

There is glutinous and starchy geng rice and there is glutinous and starchy xian rice. The difference between the grains of the glutinous and starchy rice is mainly due to the difference in the properties of the starch. Starchy rice contains more directly linked straight chain starch. It does not easily become mushy. Glutinous rice has a lot of branch chains of starch and easily becomes mushy. It can also be said that in the dry rice grain the difference in the amount of dextrin determines the difference between glutinous and starchy characteristics. An abundance of dextrin gives the rice a strong glutinous property and the rice becomes glutinous. Generally, the geng glutinous rice is more glutinous than xian glutinous rice. Rice with a medium content of dextrin is geng rice and its glutinosity is medium. Xian rice contains less dextrin and its glutinosity is weak. When analyzing gluten in iodine tincture or potassium iodide, a brown red color appears. But nonglutinous rice reacts by appearing blue. Nonglutinous rice appears transport and has a luster, whereas glutinous rice shows transparency before it is dried, but appears milky in color after being dried. The degree of glutinosity is inversely related to the expansion of rice when cooked. Therefore, nonglutinous rice is not glutinous but it expands extensively when cooked. Glutinous rice is glutinous but it expands only a little. Geng rice expands only modestly. Glutinosity and the ability to expand differ even in the same type or variety of rice. Glutinosity is related to the weather conditions at the time of maturity. If xian rice is planted in an early season and matures in summer under high temperatures, its glutinosity is poorer. If it is planted as a late season rice and matures in autumn under cool weather, its glutinosity is greater and the quality of the rice is better.

In agricultural production, varieties are planted mainly according to plant characteristics and agricultural techniques. Take the growth period for example, whether it is early rice, intermediate rice or late rice, each can be divided into early, intermediate, and late maturing varieties. The actual difference is due to local weather conditions, planting customs and planting system. For example, early xian variety Guangluai [Pan Continental

Dwarf] No 4 is an early maturing variety of early rice in southern China, but when introduced to the Yangtze River region it becomes a late maturing early rice variety. Again, Zhenzhu Ai [Pearl Dwarf] is cultiated as an early rice in south China but when introduced into the Jiangsu and Zhejiang areas it is generally planted only as intermediate rice or double cropped late rice. Varieties of different maturing periods of early, intermediate and late rice are important when combined in crop rotation and easing labor.

Cultivated varieties of paddy rice can be classified into two main categories, the short stemmed type and the tall stemmed type. Short stemmed type varieties usually have erect leaves, high utilization rate of light energy, strong tillering strength, are highly resistant to fertilizers and to lodging, and have a great potential for increased yield. Tall stemmed type varieties usually have drooping leaves, their degree of shade in the field is large, their tillering strength is weaker, they require less fertilization, easily lodge and their yield is lower. Cultivated varieties can also be categorized into three types according to the positions of the stems, i.e., the main stem and the stalks of tillers. There is the clustered type of stem and tiller stalks that grow straight and there is the dispersed type of stem and tiller stalks that grow in all directions. Between the two is the compact type.

Cultivated varieties are also markedly different in their strength of resistance against adverse conditions. In general, geng type glutinous rice has the strongest resistance to cold, geng rice is strongly resistant to cold, early xian has a weak resistance to cold and late xian has the weakest resistance to cold. Tolerance to cold can also be divided into tolerance to cold during the seedling period and tolerance to cold during the heading period. Those varieties that are tolerant to cold during the seedling period include the geng rice of the northeast and the winter grain crop of southern China. Those that are more tolerant to cold during the heading period include the late geng glutinous rice of the Taihu region. Varieties cultivated in rice fields on beaches have a higher tolerance to salinity and alkalinity. A variety's resistance to lodging is closely related to the amount of yield. In general, varieties which are more tolerant to fertilizers, shorter, and whose stems are strong and tenacious, and whose leaves are erect have stronger resistance to lodging. In disease resistance, xian rice generally has a stronger resistance to blast than geng rice, Geng rice has a stronger resistance to white leaf withering than xian rice. Different varieties vary greatly. Varieties with short stems and densely clustered leaves on the stems generally are more seriously affected by sheath and culm blight. Viral diseases are generally transmitted by the Nilaparvata lugens and the Deltocephalus oryzae when they suck on the plants and inject their poison into the plants. Therefore varieties that are strongly resistant to insect infections are not easily affected by viral diseases. Varieties whose leaves are lighter in color or whose leaves on the stems are smaller generally are less affected by the rice stem borer and the rice plant skipper. Strong or weak resistance to insect pests is closely related to the physiological, biochemical and morphological characteristics of the varieties.

The types of panicles of the varieties are also varied. Among the different shapes of panicles are the erect panicle whose axis does not grow in the shape of an arc but straight, drooping panicle which bends near the tip, arc panicle which bends like an arc, semicircular panicle which bends and forms a semicircle from the base, and bent panicle which forms a bend near the base. Among the different types of panicle stalks are clustered panicle stalks and grains that grow closely to the panicle axis, intermediately clustered panicle stalks slanting at angles less than 20 degrees and clustered, dispersed panicle stalks slanting less than 25 degrees and not clustered, and scattered panicle stalks that are almost at right angles and are scattered in all directions. The differences among the weights of the grains of different varieties are also very great, ranging from the light weight ones of a thousand grain weight of only some 10 grams to the heavy ones of a thousand grain weight of over 40 grams while most of the varieties weigh between a thousand grain weight of 22 grams and 30 grams. There are also many varieties which have a thousand grain weight of over 30 grams, such as early xian Luge and Zhulianai; intermediate xian Erlicun and Cungu; geng rice Yumidao and glutinous rice Gubanuo. The shapes of the grains can be categorized as short and round, wide and oval, elliptical, straight back and crescent.

In addition, our nation also has some special and precious paddy rice varieties, for example, the purple rice varieties of Sichuan and Guizhou provinces whose plants are purple, purple rice of Shiping in Yunnan Province, red glutinous rice of Changshou in Jiangsu Province, all of which are called "medicinal grains." There are other varieties of rice that are fragant, such as the fragrant rice of Xichenggu in Shaanxi Province and the fragrant geng glutinous rice of Yunnan Province. Their fragrance is very pleasant when cooked and is described as "the fragrance of one mu of rice is like the fragrance of flowers that can be smelled for 10 li, one family cooks and 10 families become fragrant." There is a kind of paddy rice in Sichuan and Guangxi provinces which has 2 to 3 grains in one spikelet, often called "multiple grain rice."

Then, how are all these many kinds of varieties of rice formed? We all know paddy rice is like all other living matter. It can reproduce its own kind and propagate the characteristics of its species to future generations. This retention of relative stability of the characteristics of its species is heredity. But nothing remains absolutely unchanged and all things continuously change and develop. Paddy rice also possesses the pattern of self development, ceaseless diversification and ceaseless transformation. The paddy rice varieties being cultivated at present originated as wild grown rice that was domesticated by man and evolved. At present, wild rice still grows in our nation's southern provinces of Guangdong, Guangxi, Yunnan, and Xizhang. Our country is a place of origin of paddy rice. The history of cultivation of paddy rice is very long. Cultivation of paddy rice had already begun over 3000 years B.C. during the period of Shen Nong. Paddy rice is also very widely distributed. Because of the vastness of our nation and complexity of the geography of mountains and flat lands, rivers, lakes, inland seas and beaches, thousands and thousands of changes in climatic conditions including frigid, temperate and tropical zones, and by the creative labor of broad masses of peasants, paddy rice has continuously diversified in morphological characteristics and physiological characteristics. Many mutational changes have occurred. There are differences in the reaction to sunshine and temperature conditions, late and early maturation, strength of resistance to adversity and diseases, height of the plants, size of the panicle heads, weight of the grains, having or not having awns, and color and shades of the leaves of the stem. Our cultivated paddy rice varieties gradually diversified and multiplied into many varieties and types because of interaction between opposites of heredity and mutation in a unified manner, the combined effect of natural and artificial selection and the use of various techniques of breeding and cultivation to establish and develop new traits and characteristics.

II. Inheritance of Major Economic Characteristics of Paddy Rice

The seeds of paddy rice always grow into paddy rice. They reproduce and multiply into similar individual bodies which embody the similarities of the ancestors and propagate them in the offspring. This is the phenomenon of heredity. The different paddy rice varieties of early xian Erjiuqing, early geng Nongken No 8, late xian Qiuerai, late geng Nonghu No 6 all possess different genetic material bases which can be passed on to offspring generations stably via self reproduction and propagation. The varieties' hereditary characteristics are expressed by the fact that the fixed characteristics of each variety are retained and maintained by each variety. It is because of this that after a new and superior variety is successfully cultivated, the function of this new variety in agricultural production can be brought into play continuously for a definite period of time.

Yet, no variety remains unchanged. Whether it is between the parent and the offspring generations or among individuals of the same generation, there are always some differences and none will be exactly the same. This is the phenomenon of variation. Among them, some possess only superficial changes stem and large panicles purposely planted late, in soil of minimal fertility and under conditions in which good growth and development are impossible will become short and small. But when we plant the seeds yielded by the former and provide proper conditions of cultivation, the seeds will grow into plants with tall stems and large panicles. There are also some variations which are due to inner causes--caused by changes in genetic material. These can be passed on to later generations. For example, a peasant breeder and cultivator of Chaoyang County in Guangdong Province selectively bred a short stemmed variety in the large fields of tall stemmed variety Nante No 16. This short stem characteristic could be passed on generation after generation and thus the superior variety Aihiaonante was thus successfully bred. In breeding and cultivation, what we need to study is precisely this kind of superior and inheritable variations. But it must be pointed out here that understanding the phenomenon of variations by classifying them into two categories of inheritable and noninheritable variations is relative and the understanding of such a classification must not be absolute.

What is the genetic material base--that which relates to the inner causes of the phenomena of heredity and variation in crops? At present, different views are still held. A majority of scientific experiments have proven that the material bases of heridity of characteristics are mainly the chromosomes in the cell nuclei. Although there are also some genetic material in the cytoplasm, the amount is small. The number, size and shape of chromosomes of each type of crops are invariable. Paddy rice has 24 chromosomes, wheat has 42, corn has 20 and millet has 18 chromosomes. The 24 chromosomes of paddy rice can actually be divided into two corresponding sets each with 12 chromosomes. The somatic cell of paddy rice contains two sets of chromosomes, i.e., a diploid ($2n = 24$) while the reproductive cell of paddy rice contains only one set of chromosomes, i.e., a monoploid ($n = 12$). The formation of genetic material is based on the activity of the units of heredity mainly found in chromosomes and are called genes. External causes provide conditions for change and inner causes are the bases for change. The external causes produce results through inner causes. Heredity and variation in paddy rice are precisely the results of external conditions acting upon hereditary material inside the plant. When external conditions are appropriate for the demands of the living body, a relative stability in heredity is thus manifested. When changes of external conditions bring about inner changes, they produce hereditary variations. The phenotype of paddy rice (characteristics actually manifested) can be regarded as the result of interaction of the genotype (determined by characteristics and structure of inner hereditary material) and environmental conditions.

As mentioned above, in the course of development and propagation of the individual paddy rice plant, there is both heredity and variation. Variation is absolute while heredity is relative. Heredity and variation complement each other and are the two sides of one conflicting body. Because of the unity of opposites of heredity and variation, a ceaseless development of paddy rice varieties is being pushed forward. To effectively control heredity and variation of a living body, better create new varieties of paddy rice, correct genetic theory must be used to guide breeding and cultivation practices. Thus when we conduct the selective breeding of new paddy rice varieties, we must have a basic understanding of the major characteristics of heredity and variation of paddy rice. This will help us overcome the blind exploration in the work of breeding and cultivation and increase predictability.

1. Heredity and Variation of Characteristics

The characteristics of paddy rice refer to all the physiological and biochemical characters (such as tolerance to fertilization, resistance to adverse conditions, photosensitivity, thermosensitivity) and external morphological characters (plant height, number of stems, length of panicles, color of the apicula). Characteristics can be classified into qualitative and quantitative characteristics. The former refers to qualitative characteristics such as existence or non-existence of anthocyanidin and starchiness and glutinousness of the quality of rice. These characteristics are not easily altered by environmental factors. In separated colonies of later generations of hybrid varieties, these characteristics manifest themselves as discontinuous characteristics and can be clearly differentiated. Thus the study of their hereditary dynamics is rather easy. The latter refers to quantitative characteristics such as plant height, size of panicles and weight of grains. These characteristics are affected by environmental factors more and manifest continuity in separated colonies of later generations of hybrid varieties. However, the characteristics of paddy rice must be treated in the view of dialectics. For example, the physiological and biochemical characteristics and the external morphological characteristics of paddy rice are mutually related and mutually limiting and cannot be isolated. Again for example, the height of the stem is a quantitative characteristic but the difference between the short stemmed type and tall stemmed type is qualitative. Another example is the qualitative difference between the early season type and late season type but the length of the period of growth of different varieties of the same type differs quantitatively. Numerical characteristics and qualitative characteristics are different in hereditary dynamics of later generations of hybrid varieties.

A definite degree of relationship is also manifested between some characteristics. For example, short stemmed type paddy rice varieties generally have stronger tillering strength; the type of paddy rice plants with erect leaves and deep green leaves are generally more tolerant to fertilizers while paddy rice plants with large stems and stalks often have large panicles and yield plenty of grains; varieties with large panicles and large grains mostly have higher percentages of mixed chaff and grain; and plants with purple leaf sheaths have purple apicules and stigmata. Formation of these relationships is due in part to the close connection among organic tissues (such as the color of the apicule and the color of the awn), also due in part to the multiple effectiveness of hereditary genes, and to chain heredity which is a manifestation of the fact that the hereditary genes controlling these characteristics are on the same chromosomes. Understanding the relationships among the characteristics helps us to select and breed the parents correctly in breeding and cultivation work, raise the effectiveness of the selections and determine more reasonably the size of the colony of the later generations of hybrid varieties.

The capability of passing on the hereditary characteristics of the parents to the offspring generation varies according to different characteristics. In general, the relatively stable characteristics among the quantitative characteristics under normal conditions of cultivation are not easily affected and changed by environmental conditions and thus their ability to be passed on hereditarily is stronger. For example, the ability of such characteristics as growth periods and thousand grain weight to be passed on hereditarily is stronger than such characteristics as tillering number and amount of yield. Characteristics with a strong inheritability often can be effectively fixed by selection once or a few times during the early generations in breeding and cultivation. Characteristics of weak inheritability are not easily fixed effectively by selection in the early generations and often can only be fixed effectively during the later generations or after many times of selection. In addition, a particular characteristic may possess different inheritabilities according to different parents. This should also be taken into consideration in breeding and cultivation work.

How do the changes in inheritability of paddy rice come about? Generally they are due to hybridization or the effect of external environmental conditions which cause mutation.

Paddy rice is a self pollinating crop. Hybrids are obtained by artificial hybridization of natural hybridization. This is because a hybrid combines the hereditary material ot different parents and has new and richly complicated inner causes which produce various hereditary changes. We can observe the recombination of the parental characteristics in the later generations of the hybrid and can also see the emergence of intermediate and new types as well as discover phenomena of surpassing the parents. This provides an advantageous foundation for the selective breeding of new varieties.

Mutation refers to the occurrence of sudden change in the structure and properties of genetic material within the body of the living being (such as chemical changes in the genes, changes in number and structure of the chromosomes) and thus causing hereditary variations. In nature, sudden changes brought about by violent changes in certain environmental conditions are called natural mutations. Sudden changes induced by the action of strong physical or chemical factors are called artificial mutations. Artificial mutations are conducted under environmental conditions controlled by man and thus the frequency of mutation is high and can easily be observed by man. Although most mutations produced by the effects of strong mutational factors are harmful, there are some mutations among them which are useful to agricultural production and can be selected and used.

In nature, changes in environmental conditions are often slow and in a short span of time, their effects upon the living body may be weak and they cannot bring about visible changes in the genetic material. But, when quantitative changes accumulate towards a definite direction and reach a certain degree, qualitative changes can be brought about and the heredity of the living body will change.

Although natural mutation and natural hybridization have played an important role in the long history of evolution of paddy rice, simply depending upon these natural changes obviously cannot satisfy the requirements of agricultural production which is developing daily for the varieties. Therefore, the method of artificial hybridization or artificial mutation to bring about hereditary variations is being applied on a wider and wider basis almost daily in breeding and cultivation of paddy rice.

2. Dominance and Separation

Manifestation of the characteristics of later generations of hybrid varieties, generally speaking, includes two basic phenomena: one is dominance and the second is separation.

(1) Dominance and Recessive Character of Relative Characteristics of Hybrid Varieties

All morphological characteristics and physiological and biochemical characteristics which can only be inherited by the parent generation to the offspring generation are called hereditary characteristics. Relative characteristics refer to different manifestations of synonymic characteristics such as having awns or not having awns, being tall stemmed or short stemmed, and disease resistant or not resistant to diesease.

Dominance of the first generation hybrids is the most fundamental characteristic of the pattern of change in heredity of the later generations of sexual hybridization of paddy rice. It is the major basis upon which and true and phony hybrids can be determined. When a male parent and a female parent possessing different relative characteristics are crossed, the characteristics which manifest themselves in the plants of the first generation hybrids are called dominant characteristics. Characteristics which are not manifested are called recessive characteristics. For example, the short stemmed variety Aijiaonante (height of the stem is 77.5 centimeters) and the tall stemmed variety Liantangzao (height of the stem is 108.5 centimeters) are crossed, the first generation hybrid plants manifest the tall stemmed characteristic as a tall stemmed type (height of the stem is 110 centimeters). This indicates that between the pair of relative characteristics of being tall stemmed or being short stemmed, the characteristic of being tall stemmed is dominant and the gene carrying the characteristic of being short stemmed is latent and is not manifested, thus it is a recessive characteristic. From this observation we can make correct judgments in differentiating the true hybrid from the phony hybrid whenever we cross a short stemmed variety as a female parent with a tall stemmed variety as a male parent. The hybrid first generation which is tall stemmed is the true hybrid and the hybrid first generation which is short stemmed in the phony hybrid. Again, for example, we used the early xian Aijiaonante as the female parent and crossed it with the late xian No 9 as the male parent. The resulting first generation hybrid had a growth period similar to the late xian No 9, indicating it was a true hybrid. At the same time, this indicates that between the late season type and the early season type, the late season type is a dominant trait. This kind of manifestation of dominance and recessive character of relative characteristics of paddy rice occurs frequently in first generation hybrids. Of the relative characteristics of having awns and not having awns, having anthocyanidin and not having anthocyanidin, and being not glutinous and being glutinous, the former is dominant and the latter is recessive. See Table 18 for details.

When the male parent and the female parent possess several pairs of different characteristics, it is even easier for us to differentiate the hybrid varieties. For example, when the tall stemmed Liantangzao which does not have anthocyanidin is used as the female parent and crossed with the short stemmed Aijiaonante which has purple anthocyanidin as the male parent, the first generation hybrids are tall stemmed plants possessing purple anthocyanidin. Although the characteristic of being tall stemmed is similarly possessed by the female parent, possession of purple antocyanidin as manifested in the first generation hybrid is a characteristic

Table 18. Manifestation of Dominant and Recessive Characteristics in the First Generation Hybrids of Paddy Rice

Dominant or Recessive Characteristics	Dominant Characteristic	Recessive Characteristic
Relative Characteristics		
Type of stem	tall stem	short stem
Leaf down	yes	no
Down on glume	yes	no
Awn	yes	no
Color of leaf	purple	green
Color of leaf sheath	purple	green
Color of stigma	purple	white
Color of apicule	purple	yellow
Color of rice grain	purplish red	white
Shape of rice grain	short	long
Fragrance of rice grain	fragrant	not fragrant
Texture of endosperm	not glutinous	glutinous
Length of protective glume	normal (short)	long
Resistance to blast of rice	resistant	susceptive

of the male parent and thus we can positively identify this hybrid as the true hybrid. If tall stemmed plants which do not possess anthocyanidin are found, then they are the same as Liantangzao and are thus determined to be phony hybrid plants.

It must be pointed out that the relationship between dominant and recessive characteristics is not absolute but is relative. Sometimes new characteristics different from all the parental characteristics will emerge in the first generation hybrid. Quantitatively speaking, the first generation hybrids generally manifest the intermediate type characteristics of the parents. For example, when a large grain variety is crossed with a small grain variety, the thousand grain weight of the first generation hybrid often is between those of the parents. In addition, the first generation hybrid can also manifest heterosis. Manifestation of characteristics is not only controlled by the genetic material basis but is also related to the external conditions of the living environment of the plants. All of these factors must be taken into consideration when determining the true hybrid and the phony hybrid.

(2) Separation of the Characteristics of the Latter Generations of Hybrids

Separation means the multiplicy of the manifestations of the characteristics among individual plants of the later generations of hybrids. Everyone knows when parents of stable heredity are crossed, manifestations of the individual plants of the first generation hybrid plants are basically uniform. Beginning from the second generation hybrid, separation of characteristics of various forms emerge in individual plants. Afterwards, as the number of successive generations increase and by artificial selection, the heredity tends to stabilize again and the scope of separation gradually lessens until finally a fixed line with uniform basic characteristics is obtained. The first generation hybrid has combined the heredity of the parents and possesses a greater conflict. As to the relative characteristics, although only the characteristics of only one parent is manifested, the hereditary genes of the characteristics of the other parent still exist but are latent and are not manifested. Therefore, the hereditary foundations of the hybrid is rich and complex and the male and female cells are also heterogenous. In the second hybrid generation, they separate and multiplicity emerges. In the later generations of the hybrid, the second generation's separations span the largest scope, the number of variations is the highest, and sometimes surpassing the parents occurs. Thus when genealogical methods of selection are used in breeding and cultivation, the key generation in which separation occurs the most distinctly and the effect of selection is most obvious must be seriously grasped.

3. Hereditary Dynamics of Several Major Economic Characteristics

Among the characteristics of paddy rice, many are closely related to agricultural production and possess a definite economic significance. These are called economic characteristics. The hereditary dynamics of several major economic characteristics of paddy rice are now introduced in the following:

(1) Growth Period

Selective breeding of varieties with a short growth period is extremely significant to increasing the multiple crop index, and to the avoidance of insect pests and other damages. Heredity of the growth period of paddy rice of the same ecological type is often more quantitative while heredity of the growth period of paddy rice between two different ecological types is often more qualitative. For example, Liantangzao and Aijiaonante both belong to the early xian ecological type. When they are crossed, their first generation hybrid has a growth period generally between those of the parents and separation during the second generation basically shows a continuation of the variation and quantitative heredity. The first generation hybrid of two different ecological types such as that of early xian Aijiaonante and late xian No 9 is a late season type paddy rice while the second generation hybrid separates distinctly into two large colonies, an early maturing and late maturing colony. Heredity is thus more qualitative.

We can clearly see from the two examples illustrated above that many types which surpass the parents such as those that mature even earlier than the parents or those that mature even later than the parents emerge among the second generation hybrids when separation according to growth periods occurs.

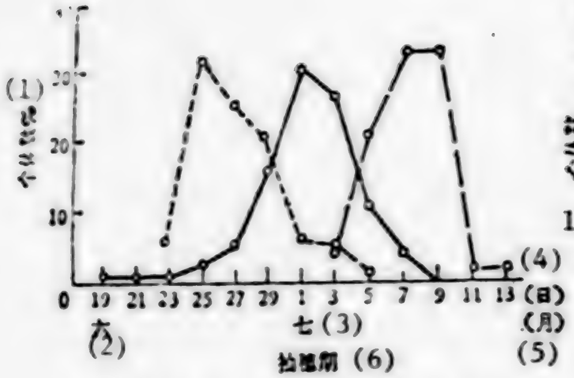


Figure 10. Separation of heading period of the second generation hybrid "Liantangzao x Aijiaonante"
-----Liantangzao;
———Second generation hybrid;
— — — Aijiaonante

Key:
(1) number of plants %
(2) June
(3) July
(4) (day)
(5) (month)
(6) Heading period

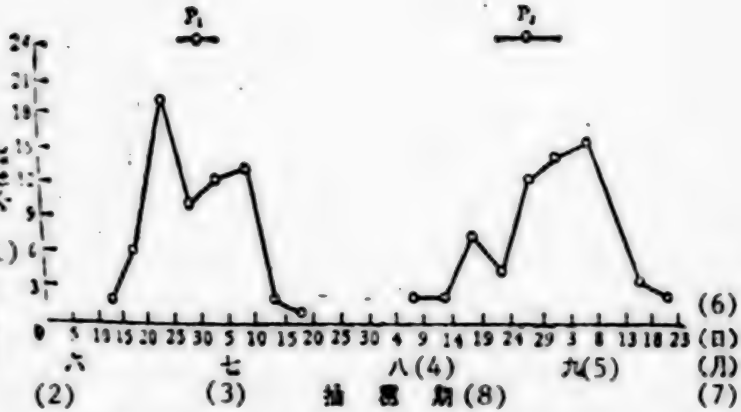


Figure 11. Separation of heading period of the second generation hybrid "Aijiaonante x late xian No 9"
P_1: Aijiaonante; P_2: late xian No 9

Key:
(1) number of plants %
(2) June
(3) July
(4) August
(5) September
(6) (day)
(7) (month)
(8) Heading period

This creates advantageous conditions for the selection among them of superior individual plants of different growth periods. As an actual example, the Chejiang Provincial Agricultural Science College crossed Ainanzao No 1 with Erjiuai No 4 and bred the Zhaoyang No 1 which matures even earlier than Ainanzao No 1. Similar phenomena of surpassing the parents also emerge among later generations of hybrids from the separation of other characteristics. These are source material which should be taken into consideration in breeding and cultivation work.

(2) Plant Type

Selective breeding of new varieties of paddy rice that are tolerant to fertilizers and produce abundant yields is a need in the ceaseless development of paddy rice production. Abundant yield and tolerance to fertilizers are closely related to the plant type of paddy rice. Short stemmed type varieties generally have erect leaves, short and strong stems and more tillers. Their ability to resist lodging and tolerate fertilizers is strong and their rate of utilization of light energy is also high, thus the foundation for high yield is established.

The height of the stem of ordinary paddy rice is a quantitative characteristic, but the short stem characteristic is a qualitative hereditary characteristic. When a tall stemmed type variety is crossed with a short stemmed type variety, the first generation hybrid is tall stemmed and in the second generation hybrid, separation of the two types occurs according to a ratio of 3:1 (tall stemmed type: short stemmed type). The short stem characteristic is recessive but as soon as it emerges it becomes a stable characteristic and is inherited. The tall stem characteristic is dominant and although some lines of plants of later generations with this characteristic still manifest themselves as tall stemmed types, a few short stemmed plants will separate from the majority of lines.

Tillering pattern is an important aspect in the formation of plant type. The form of the stem in general is a qualitative hereditary manifestation. For example, when the clustered type is crossed with a dispersed type, generally the clustered type is the dominant trait. The number of tillers is generally a quantitative hereditary manifestation. The amount of tillers is largely affected by environmental conditions and the conditions of cultivation. The effect of selection during the early generations of hybrid plants is small.

(3) Characteristics of the Panicle

The number of panicles, the number of grains and the weight of grains constitute the three main elements of yield. They are all quantitative hereditary manifestations. It has been determined by observation that in the first hybrid generation, the heterosis of the number of grains per panicle is the stronger factor among the major factors that constitute the yield and is most closely related to superior yield. The number of panicles and the weight of grains also possess definite superiority. Inheritability of the number of panicles and the number of grains per panicle is rather weak and is easily affected by conditions of cultivation. Inheritability of the weight of grains is stronger and is less affected by environmental conditions. The effect of selection during the early generations is more visible. The weight of grains is closely related to length, width and thickness of the grain. Overly long or wide grain is not easily filled. This increases the percentage of semi-filled grains. Thus thick grain types should be selected.

In the ease of threshing, generally difficulty of threshing is a dominant characteristic but sometimes the opposite occurs. Types of grains that easily shatter or those that are extremely difficult to thresh are not ideal for agricultural production.

(4) Resistance to Rice Blast

Selective breeding of disease resistant varieties is an indispensable constituent part in the breeding and cultivation of high yield crops. It is a prominent task of breeding and cultivation work similar to the task of improving the plant type and raising the rate of utilization of light energy by the varieties. The heredity of resistance to rice blast is now discussed as an example. According to the different time and place of occurrence of the pathogen of rice blast on the rice plant, blast can be classified into two types, the leaf blast disease and the panicle blast disease. Damage by panicle blast is greater. Generally speaking, there is a definite relationship between resistance to leaf blast and resistance to panicle blast. The same genetic activity is manifested. But it has been discovered that many varieties do not have the same degree of resistance to leaf blast and to panicle blast. The resistance to leaf blast of paddy rice is mainly a qualitative hereditary manifestation. Between resistance and susceptibility, resistance to disease is dominant. Xian rice is generally more resistant to blast than geng rice. The resistance of geng rice varieties to disease is mostly of the anti-infectious type (resistance to infection by pathogenic bacteria). It is a vegetative physiological resistance to disease. The varieties of disease resistant xian rice mostly are of the anti-diffusive type (resistance to the development of diseases on the paddy rice plant). They resist disease by allergic reaction.

The pathogenic bacteria of blast of rice disease contains different physiological forms. Most disease resistant varieties are resistant to some of these physiological forms but are susceptive to the other physiological forms. In agricultural production, we often encounter the situation in which the disease resistance of a variety weakens as the number of years of cultivation increases or the area of planting and cultivation increases because the physiological form of the pathogenic bacteria of blast of rice has changed. Therefore, we must emphasize crossing of varieties with genes resistant to different diseases so that new varieties with a wider range of disease resistance can be selectively bred.

(5) Protein Content

In the protein of cereal crops, the nutritional quality of protein in paddy rice is good. Protein is mainly distributed in the outer layer of the seed grain and in the embryo. After coarse rice is polished to become fine rice, the loss of protein is great. The distribution of protein in the inner and outer layers of the rice grain is more equitable in xian rice than in geng rice, in small grains than in large grains, in long grain than in short grain varieties. The loss of protein of polished rice of those varieties having a more equitable distribution of protein in the rice grains is relatively less. The content of protein in xian rice is generally higher than that in geng rice.

A clear understanding of the hereditary dynamics of the content of protein in paddy rice is still lacking. Studies have pointed out that crossing varieties with different protein contents will generally yield a first generation hybrid with a low protein content as the dominant characteristic. Inheritability of the protein content during the early generations of hybrids is rather low, therefore some people have suggested that selection based on protein content should be made from later generations.

III. The Goals and Procedures of Breeding and Cultivation

Chairman Mao always emphasized work concerned with varieties of agricultural crops. As early as 1942, he clearly pointed out: "With superior varieties, more can be harvested without increasing the labor force and fertilizers." After the founding of the nation, Chairman Mao personally drafted the "Eight Point Charter" for agriculture and proposed guidelines for scientific planting. "Variety" is an important constituent part of the "Eight Point Charter" for agriculture. All conditions of agricultural production and all techniques and measures can serve to increase production only via the "variety" of the plant. Thus, selective breeding and propagation of good varieties are the important content of the reformation of socialist agricultural techniques and are an effective measure to raise the unit area yield of crops.

"Correct or incorrect ideological and political line decides everything." Looking back over the time since the founding of the nation at the history of breeding and cultivation of paddy rice makes us realize profoundly that the revolutionary line of Chairman Mao is the basis of doing breeding and cultivation work well. Chairman Mao taught us: Socialist revolution and Socialist construction must adhere steadfastly to the mass line, the masses must be mobilized without any restrictions and a full scale mass movement must be carried out." Our nation's first short stemmed superior variety--early xian Aijiaonante was successfully bred by peasant comrades Hong Chunli [3163 2504 0448] and Hung Qunying [3163 5028 5391] of Guangdong Province.

Aijiaonante was rapidly propagated throughout our nation's southern rice regions. Paddy rice yield was visibly raised. This demonstrated the strong force of life of this new thing, short stemmed variety, and forcefully launched the mass movement of breeding and cultivation. But the gang of Liu Shaoqi and Lin Biao wanted unrealistically to revive capitalism, sold Confucianism and Mencius' philosophy on a large scale, encouraged such idealist concepts of history as "the theory of genius," "the masses are backward theory" and "the leaders are wise and the people are stupid," stubbornly pushed forward the "experts line" in the realms of science and technology and excluded the worker-peasant masses, killed and sabotaged the mass character of the movement of scientific experimentation. Because of the great proletarian Cultural Revolution and the movements to criticize Lin Biao and Confucius, the counterrevolutionary revisionist line of Liu Shaoqi and Lin Biao and the philosophies of Confucius and Mencius were criticized, the dictatorship of the proletariat is now solidified as never before, and the movement of scientific experimentation of mass character is now developing prosperously every day. Under the guidance of the proletarian revolutionary line of Chairman Mao, a working team of paddy rice breeding and cultivation consisting of revolutionary cadres and scientific and technical personnel and a backbone corps of poor and lower-middle peasants is now ceaselessly growing, gradually forming a scientific experimentation network in the mass work of selecting varieties, breeding and cultivation. Actively engaging in selective breeding and propagation of superior varieties has already become a self conscientious activity of the broad masses and the work in paddy rice breeding and cultivation throughout the nation is in an exceedingly favorable situation. According to incomplete statistics of the 1972 national paddy rice breeding and cultivation coordination conference, over 90 superior paddy rice varieties have been propagated over an area of 100,000 mu each in the southern rice regions. These superior varieties generally yield twofold or more than the local varieties. Over the past few years in the northern rice regions, over 50 new varieties have been bred successfully and are being used in production at various places. These yield between 10 percent to 20 percent more than the local varieties. Abroad, after the Philippines International Paddy Rice Research Institute successfully bred the short stemmed paddy rice variety International Rice No 8 in 1966, it was boastfully hailed as the "green revolution" in agricultural production by the West. In actuality, our nation had successfully bred and propagated short stemmed paddy rice varieties as early as the mid and late 1950's and early 1960's. From the scientific experimentation movement of mass character emerged a large group of peasant breeders and cultivators such as comrades Dent Yantang [6772 3508 2768] of Guangdong Province, Chen Hongtian [7115 3163 3944] of Zhejiang Province, and Qi Zhonglong [8016 0022 7893] of Helongjiang Province. They all stayed together with their scientific experimentation groups, consientiously studied Marxism-Leninism and Chairman Mao's writings and actively engaged in the three great revolutionary movements to carry out scientific experimentation in a big way and selectively bred a group of superior varieties at various periods and contributed towards the motherland's socialist agricultural construction. Therefore, the summary of our nation's history in breeding and cultivation of paddy rice is the history of the struggle of Chairman Mao's revolutionary line defeating the counterrevolutionary revisionist line of Liu Shaoqi and Lin Biao and the victory of the theory of knowledge of materialism over the apriorism of idealism.

1. Establishing the Goals of Breeding and Cultivation of Paddy Rice

Correctly establishing the goals of breeding and cultivation is strategically significant to breeding and cultivation work. Establishing the goals of breeding and cultivation of paddy rice must take "be prepared against war, be prepared against a natural disaster, and do everything for the people" as the guiding ideology. The direction of breeding and cultivation work towards serving socialist construction must be held firmly, taking into consideration the natural environment of the present time and the present place and the conditions of planting and cultivation and foreseeing the new demands of the developmental trends in agricultural production in the future.

Our nation has an extensive landscape and has extremely complex natural conditions and planting systems. In establishing goals for breeding and cultivation, the view that practice comes first must be upheld firmly so that conscientious surveys and research can be made and the major conflicts can be grasped and separated into stages and solved. For example, during the latter period of the 1950s, our nation's southern rice regions summarized the positive and negative experiences of many years and recognized that the problem of lodging was the major obstacle to raising the yield of paddy rice at the time. After grasping this major conflict, and inspired by the successful breeding of Aijiaonante, breeding and cultivation work in stunting of paddy rice began throughout every locality and after several years of efforts a group of short stemmed superior varieties resistant to lodging was successfully bred and propagated and the yield of paddy rice visibly increased. During the 1960s, the area of double season continuous crops of paddy rice in the Changjiang region rapidly expanded and gradually moved north. In the northern paddy rice regions, double cropping of paddy rice and wheat are also developed. Thus, closely following the solution to the problem of lodging came the problem of the maturation periods of the varieties which rose to become the major conflict in production at the time. The provinces began by selective breeding of high yielding varieties with short growth periods and selectively bred a group of early and intermediate maturing superior varieties suited to the needs of combining varieties in production. The Great Proletarian Cultural Revolution forcefully pushed forward the development of productive forces and the level of fertilization in paddy rice fields and the density of planting were further raised and higher demands were made upon the varieties' resistance to disease and insects and capabilities of high yields. Thus, the urgent task confronting breeders and cultivators of paddy rice is to increase the resistance to disease and insects and to raise the percentage and effectiveness of utilizing such external conditions as light energy and nutrients so that our nation's paddy rice production can be raised to a new height.

The total demand of a superior variety is high yield, stable yield, superior quality, suitable adaptability to reforms of planting systems and mechanized operation. But these characteristics are mutually dependent and mutually limiting. Under different environmental conditions, their manifestations are relative. Therefore, specific goals for breeding and cultivation must be aimed at the different peculiarities of different agricultural regions and the present situation of the varieties to establish the goals according to what the local circumstances dictate.

In our nation's southern rice regions, the Changjiang river valley region is heavily populated and fields are few, the soil's fertility is relatively high and the multiple crop index is high but the seasons are tight and damage by disease and insect pests is more serious. Thus, the goal of breeding and cultivating paddy rice should be based on the short stemmed type to grasp the selective breeding of new varieties of higher yields, early maturation, disease resistance and adaptability to double and triple cropping. The xian type should be used mainly as early rice so that the plants will be able to tolerate low temperatures during the seeding period and the panicle bearing period, so that the quality of the rice will be good, shattering will not easily occur, and the demand on seedling age is not exact. Productive conditions for double season rice are complex and regional restrictions of late rice varieties are great, therefore, both the geng and xian types should be taken into consideration to strengthen the selection of multiple types. The successfully bred varieties must have a flexible seedlings age, and they must be adaptable to late planting, tolerant to low temperatures during the latter period of growth, and must mature suitably early. In the Zhujiang reiver valley, the temperatures are high, the region is damp, many typhoons occur, temperature difference between day and night is small, disease and insect pests occur seriously. The goal is to breed and cultivate continuous cropping early and late rice using mainly xian type rice. The new varieties selectively bred must be tolerant to fertilizers, resistant to lodging and strongly disease resistant. The economic characteristics of the panicles must be continuously improved based on increasing the number of panicles. In recent years, the area cultivating triple season rice in the south China regions has been developed. Therefore, emphasis should also be placed on selective breeding of new varieties. Geographical features of the rice fields in the Yunnan Plateau are vastly different and the difference in weather is great. The area effectively irrigated by water conservancy projects is still small and originally the single season rice was the main crop. In recent years, the area of double season rice has been expanded. The goal of breeding and cultivation should be aimed at early maturation, tolerance to cold, tolerance to dryness, and stable and high yields. Emphasis should also be placed on the selection of multiple varieties for different regions. In general, the xian type is the major variety in the low and hot regions of the southeast. The geng type is the major variety in the cold regions of the northwest and at higher elevations.

In our nation's northern rice regions, the level of fertilization and planting density in the fields in the Beijing-Tianjin region has rapidly been raised and the area of paddy rice following wheat has continuously expanded. The major goal of breeding and cultivation at present is the selective breeding of disease resistant, lodging resistant, cold tolerant and suitably early maturing geng rice varieties. In the northeast and northwest regions of higher elevations and cold climate, the growth period of paddy rice is short, frost damage is prevalent; therefore the major goal should be the selective breeding of early maturing, disease resistant and cold tolerant geng rice varieties.

In the following, actual goals of breeding and cultivation will be explored by considering the major economic characteristics of paddy rice.

(1) Growth Period

The length of the growth period is one of the major characteristics needed by the paddy rice varieties to adapt to production. Under the same conditions of cultivation, early maturing varieties generally yield less than late maturing varieties. This is because the entire growth period of early maturing varieties is short and the accumulation of dry substances is relatively less. But to fully utilize natural conditions, raise the multiple crop index, explore the potential for increasing yield, the selective breeding of early maturing varieties is still very important in resolving the conflict between the seasons and labor availability, to assure high yields from every crop and high yields for the entire year. In addition, to avoid natural disasters and produce surplus yields, varieties with a short growth period also have their specific usefulness. Thus, the goal of the growth period of selectively bred varieties should be determined by combining the fore and after crop and the early, intermediate and late maturity periods to satisfy the need for annual high and stable yields.

(2) Surplus Yields

The fundamental factors constituting the yield of paddy rice are the effective number of panicles, the number of filled grains per panicle and the weight of the grains per unit area. Thus, these three factors constituting yield and their related economic characteristics and agricultural characteristics are the important indicators for improving surplus yields of paddy rice to be taken into consideration. For example, varieties with a strong tillering strength, high percentage of panicle formation, large panicles and abundance of grains, high fruiting percentage and heavy thousand grain weight have higher productivity. Varieties with a more clustered plant type are more suitable for dense planting which increases the total number of panicles in a unit area. Erect leaves facilitate areation and light permeability. These in turn reduce damage by disease and insects and more importantly, they have a higher percentage of utilization of light energy. To a certain degree, the amount of yield of paddy rice is determined by the amount of photosynthetic efficiency. The question as to how photosynthetic efficiency of paddy rice can be increased has become the new topic in the cultivation and breeding of high yielding varieties at home and abroad at present.

The characteristics of surplus yield of paddy rice are mutually dependent and mutually limiting. For example, varieties with large panicles often have thicker stems, weaker tillering strength, fewer effective panicles, and under densely planted conditions, the relative changes in the characteristics of the panicles are greater. Varieties with an abundance of panicles have stronger tillering strength, more effective panicles, and under densely planted conditions, the change in the characteristics of the panicles is not obvious. Practice proves that varieties with abundant panicles, strong tillering strength and a high percentage of panicle formation generally have a higher yield than varieties of large panicles. It depends upon the increased number of panicles to achieve increased yield. But one must not unilaterally argue that because of this, the more panicles the better. An overabundance of panicles will lead to detrimental changes in the characteristics of panicle grains and high yields cannot be achieved and besides, there is a limit on how many more panicles can be added per unit area. In selectively breeding new varieties, the number of filled grains per panicle should be increased upon the basis of having an abundance of panicles and raise the thousand grain weight of the grains. The number of panicles, the number of grains and the weight of grains should be dialectically unified.

In addition, emphasis must be placed on assuring an appropriate change in color during the latter part of the growth period and assuring that the stem remains green and the yellow ripe stage is appropriate. About 2/3 of the substances in the paddy rice grain are produced by photosynthesis after heading of the panicles on the plant occurs. At the same time, the photosynthesis of the leaf sheath and the stem also affects the increase in the weight of grains. Therefore, a variety with a strong root system and one which can retain more green surface area during the latter period of growth should be selectively bred so that absorption, accumulation and transportation of nutrients will be easy, and fruiting percentage can be raised and the fullness of the grains can be increased.

Finally, the ratio of grain to straw (ratio of weight of grain and weight of straw) of the paddy rice variety must also be taken into consideration as a factor affecting surplus yield, because the grain is the main object of man's harvest. Ordinary tall stemmed early xian varieties have a grain to straw ratio of nearly 1:1. Short stemmed early xian variety Guangluai No 4 has a ratio that can reach 1.36-1.54:1. Short stemmed varieties have high yields of grain and the absolute yield of straw is not lower than that of tall stemmed varieties.

(3) Stable Yield

High yields must be established on the basis of stable yields. Varieties with unstable yields are not appropriate for use in agricultural production. Stability of yield is closely related to the variety's resistance to adverse conditions, such as short stemmed variety's resistance to lodging, resistance to disease and insects, resistance to shattering, resistance to cold, resistance to salinity and alkalinity, resistance to waterlogging, and resistance to dryness.

Stunting of superior varieties is a successful experience in breeding and cultivation of paddy rice. The length of the internodes of short stemmed varieties is short, especially the first and second internodes at the base. The length of these is only 1/3 to 1/2 that of common tall stemmed varieties. The dry weight of a unit length is also clearly heavier than that of the tall stemmed varieties. The mechanical tissues of the stem are more developed, the leaf sheath wraps tightly around the internode, therefore the resistance to lodging is stronger and the plants can adapt to higher levels of fertilization, they can withstand winds and storm and rain and can support heavier grains. But overly short plants do not satisfy the requirements of production, therefore appropriate height should be obtained on the basis of short stemmed types, generally a height of between 70 centimeters and 90 centimeters is most appropriate.

Breeding and cultivation of resistance to disease and resistance to insects are an urgent measure in the struggle against diseases and insect damage. As the multiple crop index and the plant density rise and the amount of fertilizer increases, damage by disease and insects becomes more and more prevalent. To reduce the cost of using agricultural chemicals, reduce the remnant poisoning by agricultural chemicals, reduce or prevent damage by disease and insects, selective breeding of disease resistant rice blast, bacterial blight, sheath and culm blight dwarfing) and insect resistant (paddy rice borer, rice leaf hopper, cicadellidae, Cnaphalocrocis medinalis) varieties is an important goal in paddy rice breeding and cultivation at present.

Other goals, for example, are concerned with the need of early rice to be tolerant to low temperatures during the seedling period and the panicle bearing period, and the need of late rice to be tolerant to low temperatures during the later period of growth so that early rice can be sown early and late rice can head and fruit normally. It is also necessary to selectively breed paddy rice varieties that are tolerant to dryness and tolerant to alkalinity and salinity specifically for the mountain regions and the beaches.

(4) Superiority

As our nation's production continues to develop and the people's livelihood gradually is improved, it is very important to pay attention to the quality of rice concurrently with selective breeding high yield varieties.

Estimates indicate that nearly half of the total amount of protein in man's food comes from graminaceous crops, and rice is the main staple of half of the world's population. But the protein content of the present varieties of paddy rice is low, generally only 6 percent to 9 percent. Therefore raising the content and quality of protein in rice is very significant to increasing people's nutrients.

The percentage of yield of rice from the grain is related to protein content. Varieties with high protein contents have highly transparent rice grains, the rice grains are hard, broken rice is few, and the percentage of yield of rice is high. Varieties with low protein content have rice grains with large white mealy parts, a lot of broken rice, and the percentage of yield of rice is low. The percentage of yield of rice is also directly related to the thickness of the husk.

In breeding and cultivation work, varieties of rice rich in protein, having a high percentage of yield, having a lot of cutin endosperm, having a small white mealy part, having a thin husk, and the rice grains are rather thin and long (xian rice) should be selectively bred. At the same time, the living habits and customs of the masses must also be taken into consideration, such as large expandability, high culinary percentage, appropriate hardness and softness, and good taste.

(5) Adapting to the Requirements of Agricultural Mechanization

As the degree of agricultural mechanization heightens, characteristics which are adaptable to mechanized sowing, transplanting, cultivating and harvesting should also be considered when selectively breeding new varieties of paddy rice. Such characteristics as not having any awns on the grains, fast and uniform germination, rapid growth under low temperature conditions and erect seedlings are advantageous to mechanized sowing or transplanting. Varieties with clustered stems are easily handled by cultivators and harvesting machinery. Mechanized harvesting requires varieties with such characteristics that the stem is stiff and resistant to lodging, heading and maturation are uniform and that shattering does not occur easily.

2. Procedures of Breeding and Cultivation

In selective breeding of new varieties of paddy rice, the goal of breeding and cultivation is first determined, then primary material must be collected and crossed. Variant types resulting from changes induced artificially or natural changes must be selected for planting in the nursery plot for selection. Then a fixed line is chosen for line identification and experiment, including comparison of varieties and regional adaptability. Finally, the line is confidently put into mass production in large areas. This series of steps is the procedure of breeding and cultivation. The first stages involve producing new varieties and lines, the latter stages involve identification and selection of superior lines for test planting, demonstration and propagation. Of course, the procedure of breeding and cultivation does not remain unchanged but actual situations should be taken into consideration and versatility should be exercised.

(1) Collection and Handling of Primary Material

The primary material for breeding and cultivation refers to the cultivated varieties or wild types first used in the breeding and cultivation process. Having a rich source of primary material ensures a more reliable foundation for breeding new superior varieties. The primary material must be understood and studied thoroughly so that appropriate methods such as hybridization, radiation and selection by natural variations can be used and the material most appropriately used. For example, in 1962, the Chejiang Provcial Agricultural Science College used propagated variety early xian Aijiannante which had a rich array of variant types as primary material to selectively breed early maturing short stemmed varieties. As a result, the Ainanzao No 1 was selected from the natural variants. It matured over 10 days earlier than the original variety and basically satisfied the need for an early maturing variety in production at the time. Again, for example, the tall stemmed early xian variety Lucaihao has a wide adaptability, strong resistance to disease and good surplus quality. The use of this variety as primary material in various localities as parents for hybridization produced the early xian superior varieties Guiluai, xian Feng No 1 and Guangluai No 4. Thus, in the course of breeding and cultivation, the collection, study and utilization of primary material are necessary.

(2) Planting in the Nursery for Selection of Varieties

After the primary material is subjected to crossing, radiation or induced mutation and after it has been selected according to natural variant types, the chosen plants are planted in a nursery for selection of varieties so that comparison and selection can be made under relatively uniform conditions. Some natural variant types can produce a stable panicle line or line of plants after a single panicle or single plant is selected the first time. But some natural variant types and later generations of hybrids and variants resulting from induction by radiation must be selected many times before a stable line can be obtained. Therefore in the nursery for selection of varieties, generally single plants are transplanted and single plants are selected.

Throughout the entire growth period of paddy rice, the plants planted in the nursery for selection of varieties must be closely observed and the observations recorded. Survey and selection must be conducted according to the lateness or earliness of maturation by groups of plants. Superior lines which manifest signs of separation or instability should be further selected by choosing single plants according to the goals of breeding and cultivation. Superior lines that exhibit stability can be fixed as a new line by mixed threshing.

Management measures for cultivation in the nursery should be timely and refined so that the characteristics of the plants can be fully developed to heighten the accuracy of selection. The size of the nursery for selection of varieties of one breeding and cultivation unit can range between several hundred to several thousand selectively bred material according to manpower and material supply, need and possibilities. When one material source is used for breeding and cultivation, several thousand single plants will be sufficient for those generations which have many separated types or many variants such as second generation hybrids of the second generation variants induced by radiation. The later generations of plant lines with few separations generally require only 100 single plants. In the nursery, appropriate numbers of propagated superior varieties and original varieties should be planted for comparison. Harvesting of the seeds of single plants or mixed threshing of fixed types of new variety lines must be carried out carefully to avoid mixing and confusion. The harvested seeds must be bagged separately and tagged.

(3) Identification of Lines of Varieties

The goal of the experiment is to identify the yield, growth period and resistance to adverse conditions of the new varieties fixed in the process of selection in the nursery. In the course of the experiment, the manifestations of the major characteristics of each line must be conscientiously observed and recorded and the seeds must be tested at maturity and the yield measured at harvesting time. The lines which show superiority, grow uniformly, have fine features and are resistant to disease and yield 10 percent more than the contrast variety (local propagated superior variety) can be chosen for use in variety comparison experiments. Those lines of varieties whose yield is not outstanding or about the same amount as the contrast variety can be retained for further identification. Those lines of varieties which show visible drops in production and which do not possess any other special superior variant characteristics can be eliminated. Lines of varieties which are still separating and which show superiority should be singled out for continued selection.

In determining the resistance to adverse conditions, the main job is to identify the ability of the line to resist blast of rice and white leaf withering diseases. When the conditions are favorable, the line can be sent to naturally infected regions for natural determination or artificial methods of induced disease conditions can be used for determination. The degree of loss and the percentage of infected plants can be noted and the disease resistant lines could be selected and those lines that have been infected can be eliminated. In addition, in alkaline and saline regions, the determination of resistance to alkalinity and salinity is important. Shattering must be determined for plants to be planted along coastal and windy regions. Tolerance to low temperatures during the heading and fruiting stages of late rice and tolerance to cold during the seedling period of early rice should be determined in mountain regions where defrosting in the early season occurs late or where the cold front comes early in the late season.

When the number of fixed new varieties in the nursery during selection and cultivation is small, the processes of determination could be eliminated and the fixed new varieties could be directly placed in comparative testing against other varieties (lines).

(4) Comparative Testing of Varieties (Lines) and Regional Testing of Superior Varieties

The comparison of new lines determined in the identification process or newly introduced superior varieties from other localities planted in the small area under repeatable conditions against the propagated superior variety of the locality by strict observation, recording of such observations and identification and critical selection by the masses to determine one or two varieties (lines) outstandingly superior to the contrast for production and demonstration is the goal and mission of comparative testing of varieties (lines).

Regional resting of superior varieties is centrally organized and arranged by departments at the national, provincial, local and county levels. Superior varieties recommended by every locality are tested by uniform methods at many representative localities according to the needs of different agricultural regions to determine the regional adaptability of each new variety and to provide a scientific basis for propagation of superior varieties according to the dictates of the localities.

New varieties or new lines which have performed in a superior manner can be further test planted at many localities so that more poor and lower-middle peasants can directly observe the utility and productive value of the new varieties (lines) and hasten the progress of examination of superior varieties.

(5) Demonstrative Propagation and Popularization of New Varieties

Based on the comparative tests, regional tests and test planting at multiple localities, the superior varieties judged in principle to be worth propagating should be put into demonstrative propagation and cultivation for production over large areas to coordinate necessary tests during cultivation. In this way, the new varieties can be further tested in large field production so that its superiorities and shortcomings can be more truly reflected

Table 19. Reference for Arrangement of Paddy Rice Breeding and Cultivation Experiment in the Field

Name of Experiments Items	Primary Material nursery	Nursery for selection of varieties	Line determination test	Comparative test of varieties	Regional test of superior varieties
small area	Row length of 6 chi (1/3 meter), 3 rows per area	Row length of 6 chi, number of rows to be determined by the amount of seeds	Each line planted covers 60-120 square chi	Each variety planted covers 180 square chi	Each variety planted covers 180-240 square chi
Times of repetition*	--	--	1-3 times	3-4 times	4 or more times
Arrangement	In order		Intermatching	Random area or balanced	Random area or balanced
Planting method	Single plant, transplanted or directly sown. Row and plant distances between small areas are the same.		Planted in batches, row and plant distances between small areas and the number of plants in the small areas are the same.		
years of planting	According to need		one to two years each		
Contrast plants	Interplanted	Planted as contrasts among every 19-39 small areas	Planted among every 4 small areas	Random area grouping; at each repeating random number, one contrast is planted. Balanced grouping. A contrast is planted at every 2 small areas so that each small area closely neighbors the contrast plant.	

* The number of plantings in the same small area (counting the first time once).

and the corresponding method of cultivation can be discovered. On the other hand, a definite amount of superior seeds can be cultivated for use in propagation. Demonstrative propagation and cultivation should be conducted in state run propagation and cultivation farms for superior varieties and commune brigades where production levels are high. Examination of the superior varieties by the masses to finally determine their value for propagation and to develop techniques of cultivation for the varieties will enable the simultaneous popularization of superior varieties and superior methods.

Concerned units should compile information introducing the varieties based on the many years of testing, demonstration and selection for exchange and reference according to the viewpoint of one dividing into two. Popularization of new varieties must be active and careful. Emphasis must be placed on following the dictates of the local circumstances for planned expansion of the planting areas to fully develop the function of increasing production by the superior varieties.

3. Hastening the Progress of Breeding and Cultivation

According to the procedures of breeding and cultivation, collection, choosing the primary material, observation, study, selection of natural varient types or selection of variant types induced by hybridization and radiation, selective planting in the nursery for many generations and making selections many times to produce a fixed new line, determination of the lines, comparison of varieties (lines), regional testing, demonstrative planting, propagation and popularization of only one generation a year mean that at least 7 or 8 years are required to successfully breed one new variety and may even extend to over 10 years. This is clearly not suitable to the rapid developmental trends of socialist agricultural production. Thus, our nation's superior natural conditions must be utilized by planting early rice in autumn (or winter cultivation), cultivating late rice during winter, cultivating in green houses or by the method of selective breeding of two or three generations a year and test planting of newly bred lines at multiple locations early for the masses to examine them and make definite decisions to hasten propagation to shorten the number of years required for breeding and cultivation and to hasten the progress of breeding and cultivation so that high yielding and superior new varieties of paddy rice can be provided in time for our nation's agricultural production.

(1) Planting Early Rice in Autumn, Cultivating Late Rice in Winter, Multiple Generations a Year, Hastening of the Process

Planting early rice in autumn is to replant the seeds harvested from the early rice plants of the early season in autumn. In the Changjiang River valley, the safe full heading period of xian rice is before September 8, therefore replanting of the late maturing type of early xian at the same locality will not be in season and only early maturing type of early xian can be used for replanting. In the southern part of Fujian and Guangdong provinces, the temperature during autumn is high and autumn cold comes late and the early xian rice of the Changjiang River valley, whether it belongs to the early maturing or late maturing type, will be able to safely head and mature when replanted in autumn in those regions. If we want to replant the early rice for breeding and cultivation in winter and require that the harvest can still be in time for spring sowing in the Changjiang River valley, then we must bring it further south to the southern part of Hainan Island where the growth season is even longer for winter cultivation. Generally, early rice of the Changjiang River valley replanted in autumn in the southern part of Fujian Province can be sown in early August and harvested in mid November. When it is brought to the southern part of Hainan Island for winter cultivation, it can be sown during the last 10 days of November and harvested at the end of March or the beginning of April the next year.

Late rice of the Changjiang River valley cultivated in winter in the southern part of Hainan Island can be sown during the last 10 days of December or the first 10 days of January and mature during the middle 10 days of May. Late geng (glutinous) type of rice which is more tolerant to cold can be planted in the southern regions of Yunnan or Fujian provinces where the temperatures are lower than the temperatures in the southern part of Hainan Island for winter cultivation. In Yunnan Province, it can be sown during the first or middle 10 days of December, transplanted during the first or middle 10 days in February and mature during the middle 10 days in May. In southern Fujian Province, it can be sown during the middle 10 days in December, transplanted during the last 10 days of February and mature during the first or middle 10 days in June. These harvests are all in time for the sowing season of late rice in the Changjiang River valley.

The single season geng rice of the north planted in southern Hainan Island for winter cultivation generally can be sown during the last 10 days of November or the first 10 days in December and mature during the first or the middle 10 days in April of the next year.

Cultivation in green houses during winter at the original locality is also an effective method to hasten the process of breeding and cultivation, but due to the limitations of the green houses, only a small amount of plants can be planted.

It must be pointed out when planting in a different region and a different season, the reactions of some of the characteristics of the material for breeding and cultivation due to changes in weather conditions often differ to a greater extent than the reactions of plants of the locality and planted in the original season. For example, the original full heading period of early xian variety Guilusi No 8 planted as early season rice in Hangzhou occurs 4 days earlier than that of Guangluai No 4 sown and transplanted at the same time but when the Guiluai No 8 is replanted in autumn in Tongan County in Fujian Province, its full heading time occurs 6 days later than that of Guangluai No 4 sown and transplanted at the same time. Again, for example, when intermediate rice types are planted in Hainan Island for winter cultivation, their heading time comes even later than that of late rice types because of the high temperatures and the shorter sunshine periods. Changes in the growth period will also bring about changes in other related characteristics such as height of plant and the size of the panicles. Although all of these changes are not hereditary, careless analysis will often affect the accuracy of our selections. Such characteristics as plant type, thousand grain weight and disease resistance remain basically the same at different localities in different seasons during the normal seasons of those localities.

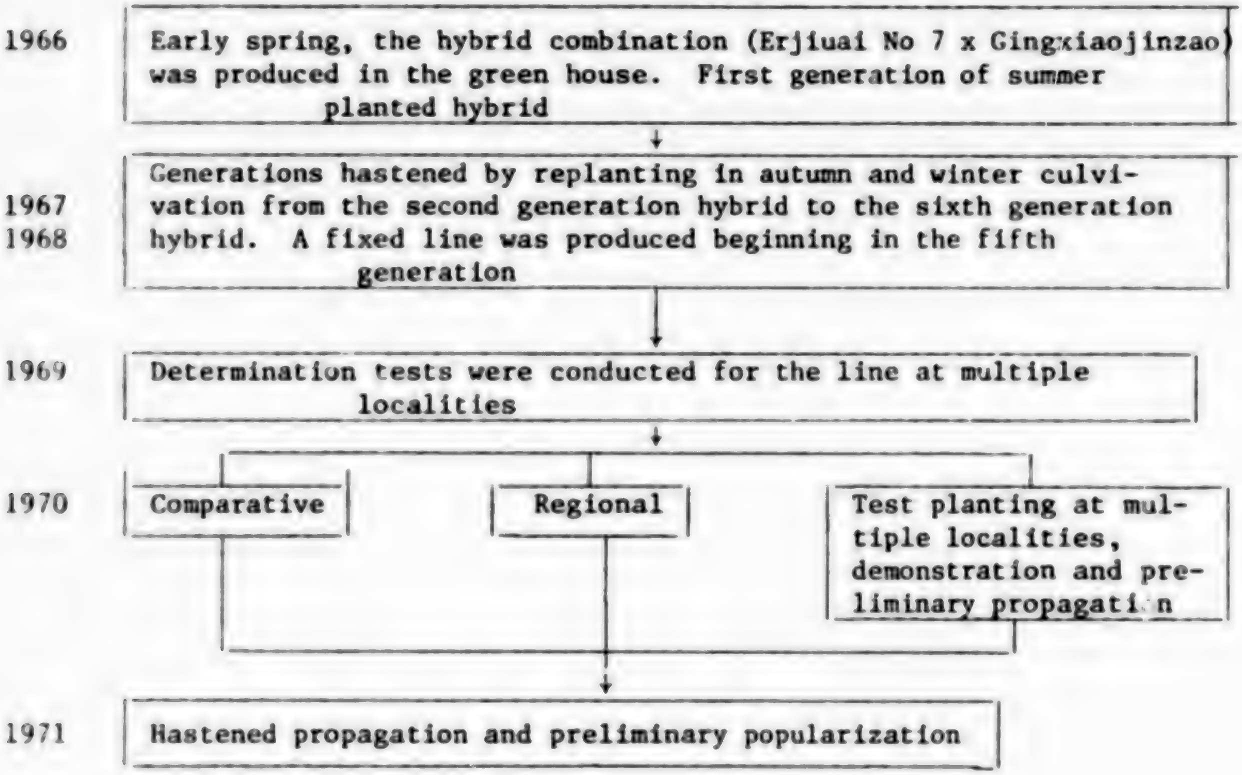
For many years, many breeding and cultivation units have obtained good results in hastening the process of breeding and cultivation by the use of selective breeding methods as replanting in autumn and cultivation in winter and by cultivating multiple generations in a year. The years for breeding and cultivation have been drastically shortened and generally only 5 to 6 years are sufficient to successfully breed a new variety for preliminary propagation in production.

(2) Test Planting at Multiple Localities, Determination by the Masses, Making Accurate Determinations, Hastening Propagation

In the work of test planting and determining new lines and varieties, routine procedures must be side stepped to hasten the procedure and shorten the years of testing. If determination is done in the first year, comparison of the varieties is done in the second year, regional experiments are done in the third year, demonstration and propagation are done in the fourth year and then popularization, then time is being wasted and this is not in keeping with the principle of achieving greater, faster, better and more economical results. Therefore, the masses must be mobilized without restrictions. Everything must be experimented with. Experimentation, demonstration, propagation and popularization by the masses must be united so that socialist agricultural production can be better served. Practice proves that the method of "test planting at multiple localities, allowing the masses to make the determinations, to make accurate determinations and to hasten propagation" in successfully breeding new varieties and lines is fast and effective. This means newly bred varieties (lines) must be distributed to representative superior seed farms and agricultural science institutes and scientific and technical groups of production teams in time to conduct test planting at multiple localities and determination. During the period between heading and maturation, the poor and lower-middle peasants, revolutionary cadres and technicians must be organized in a three way alliance to conduct critical selection in the field. After harvesting, each test planting unit must exchange its experience with other units and the total experience must be summarized and superior varieties must be critically selected and the characteristics must be understood so that appropriate and corresponding techniques of cultivation can be grasped. The new varieties which have been decided upon must be put in place and organized for substitution in time to hasten propagation and popularization. For example, early xian Erjiuqing type rice was fixed and was test planted in multiple localities for identification in the early season in 1969.

When it performed well, it was immediately replanted in autumn in small amounts. In 1970, it was tested regionally and at the same time it was propagated and cultivated demonstratively. At time of harvest, critical selection and observation was organized to determine its value for popularization. After such determination was made, it was replanted in autumn at all localities. By 1971, its early season planting area had already reached 100,000 mu and its late season autumn replanting covered about 80,000 mu. By 1972, it covered 1190,000 mu throughout the province. It took only 4 years to become the major crop of early maturing early rice in Chejiang Province.

The process of hastening the generations of Erjiuqing for breeding and cultivation is illustrated here in Figure 12.



1966 Early spring, the hybrid combination (Erjiuai No 7 x Gingxiaojinzao) was produced in the green house. First generation of summer planted hybrid

1967 1968 Generations hastened by replanting in autumn and winter culvivation from the second generation hybrid to the sixth generation hybrid. A fixed line was produced beginning in the fifth generation

1969 Determination tests were conducted for the line at multiple localities

1970 Comparative

Regional

Test planting at multiple localities, demonstration and preliminary propagation

1971 Hastened propagation and preliminary popularization

Figure 12. Illustration of the Process of Selective Breeding of Early Xian Erjiuqing

Appendix: Items to be recorded in the experiment of paddy rice varieties

1. Seedbed Period

Time of soaking the seeds, time of stimulating germination, time of sowing, time of germination (month/day)

Sowing density (jin/mu)

Quality of seedlings

Type and quantity of base manure, type, quantity and date of application of sidedressings.

Conditions of disease and insect pests and prevention

2. Examination of the Characteristics During the Period From Transplanting to Maturity

Arrangement and area of small area planting

Variety of the forecrop.

Date of transplant (month/day)

Distance between rows and plants (cun)

Number of seedlings per bunch transplanted.

Type and quantity of base manure, type, quantity and application date of sidedressings.

The number of times and the dates of weeding.

Condition of drainage and irrigation (dates and degree of holding the field)

Conditions of disease and insect pests and prevention

Recording of examination of characteristics and other recording items are listed in "standards for recording."

Standard for Recording Experimental Data on Paddy Rice Varieties

1. Time of Germination

The date (month/day) on which the first complete leaf emerges on 50 percent of the seedlings.

2. Time of Returning Green

The date on which the uppermost leaf of 50 percent of the plants after transplanting begins to extend.

3. Time of Heading

The beginning time of heading is at the time when 10 percent of the entire region's rice panicles have emerged from the leaf sheaths. The full heading time is the time when 80 percent of the entire region's rice panicles have emerged from the leaf sheaths.

4. Plant Height

One week after full heading, the height from the ground to the tip of the tallest panicle (not including the awns) is measured in centimeters as the height of the plant. Ten batches of plants in each small area's second or third row must also be measured at random.

Uniformity of plant: The uniformity of the height of the plants is measured by observation and classified into three grades classified as uniform, average and not uniform.

5. The Number of Effective Panicles per Batch

The number of panicles of each batch should be counted after the milky ripe period (those which have headed but have not fruited and tillers which have not headed are all counted as ineffective tillers, white panicles which have been damaged by disease and insects are counted as effective tillers). Between 10 and 20 batches in the second or third rows of the small area are counted.

6. Percentage of Panicle Formation

Percentage of panicle formation (%) =

$$\frac{\text{The average number of effective panicles per batch}}{\text{The average number of tallest seedlings}} \times 100$$

7. Damage by Rice Borer

If the seedlings are seriously affected by necrotic stems before heading, the percentage of necrotic stems is recorded. When counting the number of panicles per batch, the percentage of white panicles must be counted simultaneously. When only a few necrotic stems of the seedlings and a few white panicles are found, the total number of necrotic stems of the seedlings and the white panicles in each small area are counted. When occurrence of necrotic stems of seedlings and white panicles is more serious, the numbers of necrotic stems of seedlings and white panicles in representative sample areas are recorded to calculate the percentages of necrotic stems of seedlings and white panicles.

Percentage of necrotic stems (%) =

$$\frac{\text{The number of necrotic stems of seedlings in the small area (or sample area)}}{\text{Average number of tillers per batch X number of batches in the small area (or sample area)}} \times 100$$

15. Number of Grains per Panicle

Calculation of the total number of grains, and number of filled grains (including shattered grains) and the number of empty husks for each panicle.

$$\text{Percentage of unfilled grains (\%)} = \frac{\text{Number of empty husks}}{\text{Average total number of grains per panicle}} \times 100$$

16. Length of Panicle

Take five batches of plants from the second or third row inside a small area and measure the length from the node of the panicle neck to the tip of the panicle (not including awns). Then calculate the average total length of the panicle in centimeters.

17. Thousand Grain Weight

Weigh one thousand wind dried and clean grains in grams three times and obtain an average.

18. Percentage of Coarse Rice

Take 100 grams of grains and husk them into coarse rice, then remove the husks and weight.

$$\text{Percentage of coarse rice (\%)} = \frac{\text{weight of coarse rice (gram)}}{\text{100 (grams)}} \times 100$$

19. Quality of Rice

The quality of rice is recorded in three grades, top grade, medium grade and low grade as determired by a combination of factors including the amount of white mealy part, color, amount of broken rice and percentage of yield of rice.

IV. Methods of Selective Breeding of New Varieties of Paddy Rice

There are many methods of selective breeding new varieties.

Frequently used methods are breeding and cultivation of panicle lines, breeding and cultivation of panicle lines are a method using naturally superior variant types. Breeding and cultivation of hybrids and breeding and cultivation by radiation are methods of breeding new varieties by artificially creating superior variations. For example, in 1972, 28 new varieties of paddy rice selectively bred in Zhejiang Province each covered a cultivated area of over 100,000 mu. Of these, two were panicle lines covering 7.2 percent of the total area of cultivation; 22 were hybrids covering 78.5 percent of the area; and four were new varieties induced by radiation

8. Damage by Disease

The time of occurrence, area of damage and degree of seriousness of major diseases such as blast of rice, sheath and culm blight of rice, white leaf withering disease and stunting disease should be recorded. The area of damage is expressed in percentage and the degree of seriousness is recorded in three levels of light (+), medium (++) and serious (+++).

9. Lodging

The date and reason of lodging should be recorded. In recording the time of maturity, the degree of lodging and the area of lodging (%) should be observed and recorded. The degree of lodging is classified as erect, slanted, bent over or lying flat on the ground. (Erect: 0 - 15 degrees; slanted: slanting 15-45 degrees; bent over: slanting more than 45 degrees; lying flat on the ground: the entire stem and panicle lie on the ground).

10. Mass Criticism and Comparison

After the milky ripe period, poor and lower-middle peasants are invited to the fields to give criticism and make comparisons and make preliminary determination of the tested variety in the field. The comments and opinions are recorded.

11. Time of Maturation

The time of maturation is the time when over 90 percent of the grains of xian rice are yellow ripe and all grains of the geng rice are basically yellow ripe.

12. Time of harvest

Actual harvesting dates.

13. Number of Days of Growth

The number of days of growth in the field. The number of days between the second day after transplanting to the date of maturation.

The total number of days of growth: The number of days between the second day after sowing to the date of maturation.

14. Small Area Yield

When harvesting each small area, the four outermost rows of the area are removed first. Then the plants inside the entire small area are harvested. Taking the small area as unit, the plants are threshed separately, dried, cleaned and weighed, then converted to number of jin per mu.

and they covered 14.3 percent of the cultivated area. This indicates that in the course of selectively breeding new paddy rice varieties, hybridization plays an important role. Considering the time required to successfully breed a new variety, breeding and cultivating panicle lines require the shortest time. Breeding and cultivation by radiation require more time and breeding and cultivation of hybrids require the longest time. The major methods of breeding and cultivation are introduced in the following:

1. Breeding and Cultivation of Panicle Lines

The method of breeding and cultivation of panicle lines is also called selecting the superior from the superior or selective breeding of lines. The method is to select from originally propagated superior varieties or newly introduced varieties superior single panicles or single plants according to the requirements specified in the goals of breeding and cultivation. After comparison and identification, these single panicles or plants are propagated to become a new superior variety.

Widespread production practices prove that all things are mobile and develop. After a variety has been planted for many years, it will necessarily change. This change is due to natural hybridization or caused by external conditions. Some changes are good and some changes are bad. Thus, purity of varieties is relative while impurity is absolute. Because all varieties contain natural changes, rich material conditions are provided for the breeding and cultivation of panicle lines. As long as we select the variants with superior characteristics from among them according to the needs of production, we can gradually and successfully breed new varieties that are completely different from the original. Many superior varieties used in production such as early xian Aijiaonante, Ainanzao No 1, intermediate geng Fanghong No 1, late Genghuxuan 19, and Jianong 14, have all been bred by the method of breeding and cultivation of panicle lines.

(1) Indicators and Methods of Selection in the Fields

In breeding and cultivation of panicle lines, the type of variants to be selected must first be made clear. Generally, we always ask that it possesses more superior qualities in various aspects but in actual selection in the fields, the major conflicts must be taken into consideration as the major indicators for selection according to the needs of development of production and the characteristics of the original varieties of the locality and the time. For example, if the original variety matures rather late while an early maturing variety is urgently needed in agricultural production, then we can take the characteristic of early maturation as the major indicator for selection in the field. Again, for example, in areas where blast of rice disease is rampant, we can take strong disease resistance as the major indicator, etc. In this way, the major indicators can be pinpointed and other characteristics are also taken into consideration and breeding and cultivation of panicle lines will have more of a chance to succeed.

Selection of single panicles or single plants generally should be done among propagated superior varieties. This is because the propagated superior varieties themselves have a higher productivity and can also adapt to the natural environment and conditions of cultivation of the locality. On this basis, a new type possessing superiority in a certain aspect is selected. Then it will have its value for propagation and utilization. Of course, selecting among varieties newly introduced from elsewhere or from other material sources can also be done if superior variant types emerge.

Selection in the field should mainly be done in large production fields where there are relatively more variant types. There is no set rule for how much material is needed for making the selection. This is because among the various variants one sees, some are inheritable and others are not. If a superior piece of material which is truly a result of hereditary variation is selected, then of course only one panicle and one plant are sufficient. But generally speaking, the chance of this is very slim and besides mainly selecting characteristics, consideration must also be given to whether other characteristics are good or not. Therefore, more material needs to be appropriately selected so that varieties satisfying the goals of breeding and cultivation can be selected with more confidence. For example, the selective breeding of Ainanzao No 1 took into consideration early maturation as the major indicator. A total of 1143 early maturing single panicles were selected from Aijiaonante and then further selection was made according to the manifestations of the characteristics of the panicle lines of later generations.

Selection of material in the field involves identifying the locality, original variety and indicators of selection. Then a finer selection is made indoors to eliminate material with undesirable characteristics such as susceptibility to disease and insects. Finally the selected material is threshed or its single panicle is stored.

In making selections in the fields, the mechanically mixed material must be abandoned to prevent mistaken identification and selection of plants of different varieties mixed with the material as a variant type.

(2) Planting of Panicle Lines (Plant Lines) in the Nursery for Selection of Varieties

The single panicles (single plants) selected the previous year are planted as lines taking the panicle (plant) as the unit. Each line occupies one to two rows (directly sown or transplanted, each row is 6 chi long, distance between rows is 5 to 6 cun, distance between plants is 4 to 5 cun) with only one plant occupying one hole. A contrast variety is interplanted as every 19 to 39 panicle (plant) lines. The contrast variety should be a propagated variety corresponding to the different goals for selection. However, the original variety should also be interplanted approximately for comparison.

Table 20. Efficiency of Selection of the Characteristic of Early Maturity of Aijiaonante (Zhejiang Provincial Agricultural Science College, 1963-1964)

Manifestation of the single panicle during selection in the field	Number of panicles selected	Early maturing panicle line		Panicle lines that manifest early maturity obscurely		Panicle lines that do not manifest early maturity	
		Quantity	%	Quantity	%	Quantity	%
Extremely early maturing	74	25	33.8	27	36.5	22	29.7
Early maturing	1069	35	3.3	451	42.2	582	54.5
Total	1143	60	5.2	478	41.8	604	53.0

Management of cultivation in the experimental field should be the same as that for ordinary fields but certain appropriate adjustments should be made according to the indicators of selection. If the goal is to selectively breed a high yielding variety that is tolerant to fertilizers, applications of fertilizers should be appropriately increased. In general, disease prevention measures are unnecessary so that material susceptible to disease can be eliminated early. Field management must be recorded in time and systematic observation and records must be made of the growth and development of the rice seedlings.

At harvesting time, critical selection in the field can be made based on the results of observation and records. Those panicle (plant) lines which are regarded as satisfying the goals of selective breeding must be singly harvested and singly dried. When the conditions are right, analysis and testing of the yield and the seeds must be conducted. Further selection of single plants must be conducted for those few panicle lines which perform well but which are still separating. Those panicles (plants) that perform poorly are eliminated.

The selected superior panicle lines whose heredity has stabilized can be placed for line identification testing the following year. Procedures that follow have been explained in the previous section.

2. Breeding and Cultivation of Hybrids

Hybridization is the most commonly used method that is effective to artificially create superior variant types. Breeding and cultivation by hybridization is the method of obtaining new varieties by producing a hybrid from the combination of the female and male cells of two varieties or types and by selection, cultivation, identification and critical selection. The major feature of this method is that the superior characteristics of the parents can be conscientiously combined and new characteristics surpassing the parents or new characteristics not possessed by the parents can be obtained in the successfully bred high yielding variety of superior quality.

(1) Correctly Select and Match Parents for Hybridization According to the Goals of Breeding and Cultivation

The male and female parent varieties used in the hybridization are referred to in general as the parents of hybridization. According to the goals of breeding and cultivation, the key to the success or failure of breeding and cultivation hybrids is how to correctly select and match the parents of hybridization. Then how are parents correctly selected and matched? Breeding and cultivation practices prove that the following points should be taken into consideration in the selection and matching of parents of hybridization:

1) The parents must possess the superior characteristics required by the goals of breeding and cultivation. For example, in planning to selectively breed a short stemmed variety, there must be at least one parent that is a

short stemmed variety. To selectively breed an early maturing variety, at least one parent must be early maturing. When cultivating a disease resistant variety, at least one parent must be disease resistant. To cultivate a new early maturing, disease resistant and high yielding short stemmed variety, then the parents must separately possess all these superior characteristics.

There is no variety that is perfect. Two varieties possessing more advantages than shortcomings and whose advantages and shortcomings are mutually supplementary should be selected as parents of hybridization. Both parents having the same serious shortcomings must be avoided.

2) Relatively speaking, propagated superior varieties generally have more advantages than shortcomings and are adapted to local production conditions. Using the propagated varieties of a locality as parent for crossing with some varieties possessing special superior characteristics often produce more superior varient types in the hybrid generations and the hereditary characteristics stabilize more easily and new varieties can be created within a relatively short time. At present, many varieties used in production have been successfully bred by this method. For example, Zhejiang Province's early xian Erjiuqing is the hybrid selectively bred from the propagated variety Qingxiaojinzao and Jiuerai No 7. The late geng Nonghu No 6 is the hybrid selectively bred from the propagated variety Nongken 58 as a parent and Laohu rice.

3) Selection of varieties of different ecological types or varieties that are from geographically distant localities for hybridization. The scope of variation of the hybrid generations is closely related to the degree of ecological, geographical and lineal differences between the two parents. The greater the differences between the male and female parents the greater the scope of variation of the latter generations and the more opportunities there are for selecting superior characteristics. At present, the methods of crossing early and late rice varieties, xian and geng rice varieties, and domestic and foreign varieties are often sued to enrich the hereditary bases for hybridization and expand the scope of variations of the later hybrid generations. Desirable achievements have been obtained.

In selecting different ecological types or geographically distant varieties for hybridization, the propagated superior variety of the locality should generally be used as the female. This is because it has a stronger adaptability to the weather and soil conditions and stronger resistance to the diseases and insects of the locality. This method of matching often makes it easier to select new varieties that are suitable for cultivation at the locality. In addition, when selecting different ecological types or geographically distant varieties for hybridization, the differences between the parents are great and the later hybrid generations often do not easily stabilize. Therefore back crossing and multiple crossing methods should be used and work in the selection and cultivation of later hybrid generations should be strengthened.

4) Varieties with better combinative strength in hybridization should be selected as parents. Generally speaking, a superior variety often is simultaneously a good parent for hybridization but not necessarily all superior varieties are good parents for hybridization. Whether a variety is a good parent for hybridization depends on whether the variety's combinative strength is good or poor. Using varieties with good combinative strength as a parent for hybridization makes it easy for the superior characteristics to manifest themselves in the later hybrid generation. Using varieties with poor combinative strength as a parent for hybridization will often prevent the achievement of certain predicted results. Whether the hereditary basis of the parents is broad and whether some characteristics of the parents have stronger inheritability all affect the performance of the later hybrid generations. Analysis of the parental sources of the 76 early and intermediate hybrid xian varieties successfully bred, test planted and popularized in Zheijang Province shows that according to their surplus yield characteristics, Erjiuai and Guangchangai are better parents but according to resistance to disease, Zhenzhuai and Lucaicaihao are better parents. Accumulation of the experiences of breeding and cultivation of various localities and strengthening the study and analysis of combinative strength of the varieties of the parents will help raise the predictability of breeding and cultivation of paddy rice hybrids. But at present, a total understanding of the primary material of the varieties is still lacking, the hereditary patterns of the characteristics of the parents are still not grasped profoundly enough, and in general it is better to produce more hybrid combinations to increase the chances for selection.

(2) Methods of Hybridization

After the parents for hybridization have been chosen, the method of hybridization to be used must be considered. Generally there are three methods of hybridization, single cross, multiple cross and back cross. A male and a female combine to form a pair. This is called a hybrid pair usually designated as "A X B", where "X" represents a cross. The female is represented by the letter in front and the male is represented by the second letter at the back. For convenience, the female can be represented by "♀" and the male by "♂".

1) Single Cross

Single cross is also called paired cross. It is the breeding of a new variety by crossing two varieties and it is the most commonly used method of breeeding and cultivation and appropriate selection of the parents, single cross yields fast results. Such propagated varieties as Erjiuqing, Guangluai No 4, Hongmeizao, Zhenzhuai, Nanhing No 11, Jigeng 53, Hingyu No 1 and Nonghu No 6 are all bred from single crosses.

2) Multiple Cross

Multiple cross is hybridization of three or more varieties. There are many different forms of multiple crosses. For example, a single crossed hybrid crossed with a third variety is called triple cross, two different single crossed hybrids crossed with each other is a quadruple cross, etc. Multiple crosses is generally conducted in the first hybrid generation but may be conducted in later generations for selecting plants. The purpose of multiple cross is to combine the advantages of many varieties to achieve even more satisfactory results than from single cross. Multiple cross involves more parental varieties. The hereditary bases of the hybrids are more complex. The scope of variation of the later generations is broad. Therefore, the colonies of the later generations of the hybrid must be correspondingly enlarged and the time required to produce a fixed line is longer. Many varieties have been bred successfully by multiple cross. For example, Beijing city's Jingfeng No 5 is bred from (Taizhong 39 x Shuiyuan 300 grains) as the female parent and (Nonglin 29 x Nongken 19) as the male parent. Guangdong Province's Zhaiyeqing is bred from the multiple cross between the third generation superior single plant of (Hualongshuitiangu X Tangzhu) as male and Jiduilun.

3) Back Cross

The hybrid obtained from hybridization crossed again with one of the parents is called back cross. The parent used in the back cross is generally called the recurrent parent. The parent that is not used in the back cross is called the nonrecurrent parent. The back cross method is a frequently used and effective method in breeding and cultivation of disease resistant varieties and the breeding and cultivation of hybrids of distantly related parents.

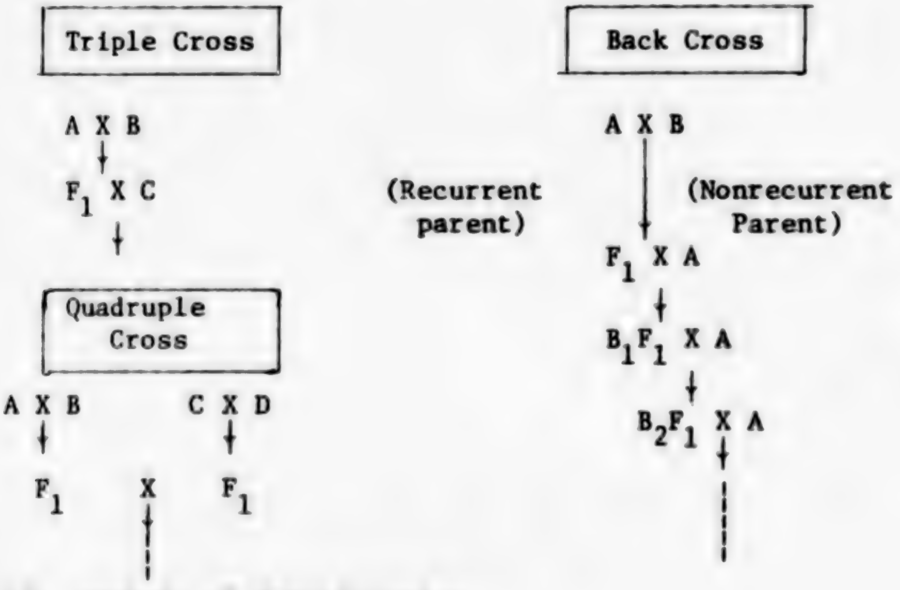


Figure 13. Methods of Hybridization

F_1 : First generation hybrid
B_1F_1 : First hybrid generation of the first back cross
B_2F_1 : First hybrid generation of the second back cross

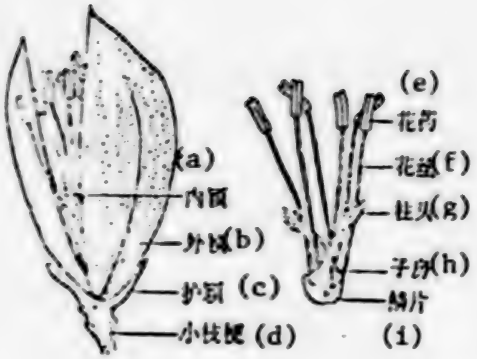


Figure 14. Structure of the Flower Organ of Paddy Rice

Key:
(a) inner glume
(b) outer glume
(c) protective glume
(d) stalk
(e) anther
(f) filament
(g) stigma
(h) ovary
(i) scale

The purpose of back cross is generally to improve the individual shortcomings of the originally propagated varieties. For example, a certain propagated variety has superior basic characteristics but its disease resistance is weak. Then the back cross method can be used to improve it. At the beginning, the propagated variety is used as the female and another variety with a strong resistance to disease and strong inheritability is used as the male. In the back cross, their hybrid is used as the female and the originally propagated variety is used as the male (recurrent parent). Then, the single plant with a strong disease resistance selected from this back crossed hybrid is used as the female to be crossed again with the recurrent parent. After many repetitions, the variety thus bred not only can incorporate the strong disease resistance of the nonrecurrent parent into itself but also can retain or strengthen the basic superior characteristics of the originally propagated variety. The number of times of back crosses should be determined by whether material satisfying the goals of breeding and cultivation can be selected from the later generations obtained.

If the characteristics to be induced are recessive characteristics, the self cross must be conducted after every back cross so that a single plant possessing the induced characteristic can be selected from the separated later generations and the single plant is then used for a repeated back cross.

(3) Paddy Rice's Hybridization Techniques

After the combinations for hybridization have been determined, t[illegible] of hybridization can be started. Hybridization is the use of artificial methods to pollinate the stigma of the pistil of the plant of the female variety by the pollen of the plant of the male variety. A hybrid is formed after fertilization and fruiting. To conduct such work, the structure of the organs of the paddy rice flower must be understood and the flowering habit of the plant must also be understood so that the male and the female plants can flower together.

1) Structure of the Organs of the Flower of Paddy Rice

The organs of the flower of paddy rice mainly consist of five parts, the protective glume, the outer glume, the inner glume, the stamen and the pistil. On the outside of the flower are two small and thin protective glumes, one outer glume, one inner glume, which later grow into the husk. Each flower has six stamena surrounding the pistil. Each stamen consists of a thin filament and a rectangular anther. Inside the anther are stored light yellow pollen. The pistil grows in the center of the flower and consists of an ovary, two feather-like stigmata and style. After fertilization, the ovary enlarges and matures to become the rice grain. A detailed illustration is shown in Figure 14.

2) Flowering Habits of Paddy Rice

The panicle of the paddy rice plant begins to flower when the boot leaf emerges. The flowering order is: on a single plant, the main panicle flowers first, followed by tiller panicles; on a single panicle, the upper branch stalks flower first, followed by branch stalks at the lower part; on a single branch stalk, the small flower at the tip flowers first, followed by the small flower at the base, and then followed in sequence downward. Daily flowering time is between 7 am and 4 pm. The peak flowering time is between 9 am and 1 pm. The daily flowering time often varies according to changes in weather conditions and according to different varieties. Early season rice heads when the temperature is rather high and the daily flowering time is relatively early. Late season rice heads when the temperature is rather low and the daily flowering time is relatively late. In the same season and climate, clear weather and high temperatures will cause the flowering time to occur early. Damp and cloudy weather or lower temperatures will delay the flowering time. The flowering time of xian rice is generally earlier than that of geng rice. The daily flowering times of the same types of plants of different varieties are different. Under natural conditions, the life of the pollen of paddy rice is about 5 minutes while the ability of the pistil to be fertilized by the pollen can last 3 or 4 days.

3) The Method of Adjusting the Flowering Times of the Parents So That They Occur at the Same Time

After the pair of plants of hybridization has been decided according to the goals of breeding and cultivation and principles of selecting the parents for hybridization, and if the growth periods of the parents are different, then corresponding measures must be taken to adjust the flowering times of the parents so that the flowering times will meet to facilitate hybridization. The following are often used methods:

(1) Sowing at Separate Times

If the growth periods of the parents for hybridization are already known, the parent with the long growth period should be sown early and the variety with the short growth period should be sown late so that they will flower at the same time. When it is difficult to determine whether they should be sown early or late, the same parent for hybridization can be sown at separate times to prolong the flowering time so that it will meet the flowering time of the other parent for hybridization. Generally, the variety with the short growth period is sown at separate times to match it with the growth period of the variety with the long growth period. When an early rice variety is crossed with a late rice variety, it is best to plant the early rice variety during the late season and use the method of sowing it at separate times so that its flowering time will meet that of the late rice variety.

(2) Treatment in Short Daylight Conditions

Varieties of the late rice type are short daylight crops. They are strongly sensitive to light. Treatment under short daylight conditions can cause it to head and flower early. The method of short daylight treatment is: to cover up the entire rice seedling with a black covering every day from 5 pm in the afternoon to 8 am the next morning. At localities where conditions are favorable, a dark room can be used. The rice seedlings are moved from the dark room every morning at about 8 am and returned to the dark room at about 5 pm, thus exposing the seedlings to only 9 to 10 hours of short daylight every day. The time to begin such treatment depends upon the time of hybridization we want. In general, the treatment should begin 40 to 45 days before heading and last until 5 to 7 days after young panicle differentiation.

(3) Other Methods

When it is discovered that one of the parents of hybridization has already headed while the other has not yet headed, the panicles of the parent which has already headed can be removed or "cut the panicles to keep the plant young" so that they will grow again, thus delaying the flowering period. If the parent that has not headed is about to head, the part of the panicle to be cut can be higher or just the ears (fruiting panicles) are removed. Otherwise, the part to be cut can be lower.

4) Operating Procedure of Hybridization

The procedures of hybridization generally include selection of the panicle, emasculation, preparation of the panicle, pollination, bagging and identification.

(1) Selection of the Panicle

The rice panicles of the plants of the female variety whose leaf sheaths of the boot leaves have already headed about two thirds and which are about to flower that day should be the targets for emasculation. Panicles which have a small number of spikelets on the tip that have already flowered and are about to reach their flowering peak that day should be the targets for emasculation.

(2) Emasculation

After the above panicles have been selected, they can be emasculated. Emasculation is to use artificial methods to remove the stamena of the rice panicles of the female variety used in hybridization or to sterilize (to kill) the pollen. Emasculation can prevent self pollination and force the pistil of the plants of the female variety to accept the pollen of the male variety to achieve hybridization. At present, the commonly used methods include the use of warm water for emasculation and sometimes the removal of glumes to achieve emasculation.

Emasculation by Warm Water

This method is based on the difference in the tolerance to high temperatures of the pollen and the pistil. The pistil is more tolerant to high temperatures and the stamen is less tolerant to high temperatures, therefore the use of water of a certain temperature to treat the spikelets can sterilize the pollen but will not affect the vitality of the pistil. The actual procedure is like this: About one hour before flowering, the leaf sheaths of the rice panicles of the plants used as the females and destined for emasculation are opened up slightly to expose the neck of the panicle. Then soak the entire panicle into a container filled with warm hot water of between 43 and 45 degrees C for 5 to 8 minutes. The higher the temperature of the water the shorter the time of soaking and the lower the temperature the longer the time of soaking. Xian rice can be treated in lower temperature water or for a shorter time and geng rice can be treated in higher temperature water or for a longer time; the more frequently used water temperature is 45 degrees C and the duration is 5 minutes. In this way, emasculation can be done thoroughly, phony hybrids will be few and the fruiting percentage will be high. After treatment by warm water, the rice panicles are taken out of the water and the spikelets that have already developed completely and matured can flower immediately or after a few minutes. Spikelets that have not developed completely or matured but have already been pollinated will not flower. During treatment of the panicles with warm water, the panicle neck and stems should not be broken.

The Method of Emasculation by Removing the Glumes

Between 4 pm on the day before hybridization and 7 am on the morning of the day of hybridization, 2/3 to 1/4 of the glumes of the spikelets which are on the panicles of the rice plants used as females and which are expected to flower on the day of hybridization (when the anther has already occupied 2/3 of the space inside the glumes) are cut away. After a few minutes of waiting, the filaments will extend and the anther will emerge from the glumes. At this time, all six anthers are removed with pincers. It is important not to break the anthers because if the anthers are broken their pollen will drop onto the stigma and cause self pollination and produce a phony hybrid.

(3) Preparation of Panicles

After the rice panicles have been emasculated by warm water, all spikelets that have not flowered are removed from the panicle, leaving only the spikelets that are flowering with pollen that have been sterilized. If the method of removing the glumes has been used, and the rice panicles have been emasculated in this way, then all spikelets that have already flowered and all those with immature pollen must be removed, leaving only the spikelets whose male ears have been removed by pincers. Then a paper bag is used to cover the substance up to prevent other pollen from causing impurities.

(4) Pollination

After emasculation and preparation of the panicles, pollination can be performed. Pollination is to pollinate the stigma of the female by the pollen of the male. The frequently used methods of pollination are:

The Use of Pincers

The developed and mature anther on the panicles of the plant of the male variety (when the anther has already reached the tip of the glume when seen against sunlight) is taken with pincers and placed inside the empty glume of the panicle of the emasculated female rice plant. The anther is then broken with the pincers and the pollen is allowed to drop on top of the stigma.

Shaking the Pollen

The flowering panicle of the male it taken and placed on the panicle of the emasculated female which is inside a transparent and open plastic bag. The neck of the panicle is lightly turned or patted with a finger so that the pollen scatters onto the stigma. If the female variety has completed emasculation but the male variety has not yet flowered, then the male's panicles can be covered with a black paper bag for about 10 minutes on a clear and sunny day to stimulate earlier flowering. On a cloudy and rainy day, the empty glume of the spikelets of the male that have already matured can be opened up with pincers or cut away 1/3 of the glumes that are about to flower but have not yet flowered on the panicle of the male plant and then shake the pollen onto the stigma. After a hybrid set is formed, the utensils used must be washed and cleaned or wiped with alcohol before using again to prevent mixing the pollen.

Bagging and Identification

After pollination is completed, the substance is placed lightly in a transparent paper bag to prevent other pollen from pollinating and making the content impure. The bottom of the paper bag must be sealed with a paper clip. When pollination was done by shaking, the upper opening of the paper bag must also be sealed. A small tag is attached and a pencil is used to write on the tag the names of the male and the female parents, the number of spikelets used for hybridization and the date of hybridization.

After hybridization, the hybrid plants must be cared for to prevent breaking, lodging and damage by field rats and birds. When the seeds mature, the paper tags must be included with the harvest. Hybrid seeds produced by different hybrid pairs must be harvested, recorded, dried and stored separately. They must never be mixed together.

(4) Cultivation and Selection of Later Generations of Hybrids

Obtaining a hybrid through artificial hybridization is only a beginning in the entire process of breeding and cultivation of hybrids. Most of the work involves the cultivation, selection and identification of the later generations of the hybrids. It has been mentioned previously that the characteristics of the later generations of hybrids are kaleidoscopic. There are many separated types and many types that have characteristics surpassing those of the parents often emerge. Scientific methods of selection must be used to selectively breed the ideal superior variety among them.

1) Selection by Lineage

The method of selecting by lineage involves continuous and repeated selection of single plants from the later hybrid generations by planting separated lines and selecting the superior plants among superior lines until a fixed new variety line is formed with stable characteristics within a line of plants. Then, the plane line is identified, critically compared and cultivated in a new superior variety. Thus the method of selection by lineage is also called repeated selection of single plants. Strictly speaking, the method of selecting lines by lineage involves systematic numbering of each generation of plant lines. Then, by looking up the number of the selected single plant, one can obtain its generation and the line it belongs to and trace the origin and the lineage of plant line easily. The procedures of the method of selecting lines by lineage is more complex but enable early, objective and rigorous identification and selection of each plant line. The results of such selections are good and thus it is one of the most frequently used methods of selection in breeding and cultivation of hybrids.

Cultivation and Identification of the First Generation Hybrids

After the hybrid seeds are sown, the first generation of hybrid plants is designated as (F_1). F_1 combines the hereditary characteristics of the parents and contains greater inner conflicts. Its heterosis is more pronounced. F_1 plants should be planted sparsely and singly in groups, each group consists of about 10 plants. The amount of seeds used should be sufficient to produce enough F_2 plants. To differentiate the true hybrids from the phony hybrids, the male and female parents should be planted along side the hybrids (or nearby) for comparison. The characteristics of the F_1 plants should be closely observed. True hybrids are those plants that manifest characteristics of the male parent, that manifest themselves as intermediate types of the male and female parents, that manifest new characteristics, or possess obvious heterosis. Those plants which manifest characteristics similar to those of the female parent are usually phony hybrids resulting from self pollination and fruiting and should be eliminated.

The method of selecting F_1 plants is determined by whether the hereditary basis of the parents is a pure combination or an impure combination. If it is a pure combination (such as a cross between two stable varieties), then each plant of F_1 will manifest uniform characteristics. At maturity, they can be harvested by groups without distinction and stored for sowing of the second generation hybrids (F_2). In this case, groups are not eliminated except those groups that have been seriously affected by disease. If the combination is impure (such as multiple crossed groups), the characteristics of the plants of the F_1 generation will not be uniform and separation will necessarily occur. In this case, more plants for the F_1 generation are required, generally several dozen plants or even a hundred plants to make it easier to select superior single plants from among them. The F_2 generation is planted in single plants and the remaining plants can be harvested without distinction after removing diseased plants and plants of poor quality.

Separation and Selection of Second Generation Hybrids

The scope of separation among the plants of the second generation hybrids is wide and there are many variant types. To select superior plants satisfying the expected goals, F_2 plants must be numerous. Only in a sufficiently large colony can all characteristics become separated and all variant types have a chance to manifest themselves. Generally, groups of 2,000 plants should be planted singly and groups with superior manifestations should be planted singly in groups of 5,000 or more plants. Planting too few will affect the probability of emergence of superior single plants. The most appropriate number of plants to be planted for the F_2 generation should also be determined by the number of groups and the distance of the relationship between the two parents. If the parents are distantly or remotely related or produce a few number of groups, more plants should be planted for each group of F_2. If the parents are closely related or produce a large number of groups, fewer plants can be planted for each group of F_2. The F_2 plants should be planted at the original locality in their normal seasons. At a definite distance among them, a contrast variety should be interplanted for comparison.

F_2 is the key generation in the selection of later generations of hybrids. The standard for selection should be more rigorous because characteristics with strong inheritability such as plant type, resistance to disease, growth period and thousand grain weight will not change much in the later generations after F_2 is correctly chosen. Characteristics with weaker inheritability such as the number of tillers, and the number of grains per panicle should not be strictly selected. In the selection, the groups must first be determined and then superior single plants can be selected from the preselected groups. The indicators for selection should be based on the goals of breeding and cultivation and the goal of producing the groups. All such characteristics as good combining characteristics, high productivity by the single plant, strong resistance to disease or special superior characteristics should be considered for selection of single plants, should be thorough and conscientious and can be conducted according to the times of maturation. Preliminary selection and tagging can be made during the heading period and semi-final selection can be done during the period of maturation. Final selection and testing of the seeds can be performed indoors.

The selected single plants of F_2 must be individually threshed and numbered by groups (if a rigorous selection by lineage is not used, numbering is not necessary, the same applies to later generations) for planting the F_3 generation.

The seeds of single plants selected for the generations following the F_3 generation must all be grouped and the plants must be separately sown and transplanted. In this way, the individual plant lines of the third generation hybrids (F_3) are formed. Generally, separation still occurs in the plant lines of the F_3 generation but this occurs far less than in the F_2 generation. Therefore only 100 to 150 single plants are needed for each plant line. A contrast variety is planted among every 19 to 39 lines of plants as reference when selection is performed in the field.

Selection of F_3 plants must be done according to records of field observations of the entire growth process of paddy rice. The standard for selection is more rigorous than for F_2. In making selections in the field, the line must first be selected and then the plant. This means the plant line must first be decided and then the superior single plants in the selected plant line are selected. Since separation occurs less among each plant line and the differences are not great, only 3 to 5 single plants are selected from each selected plant line but more single plants can be selected from plant lines that manifest especially superior characteristics and inferior plant lines can be eliminated totally.

The single plants selected from F_3 for planting of the F_4 generation should still be planted according to plant lines by groups. The planting method for the F_4 and later generations is the same as that for F_3 but the number of rows of single plants can be reduced and three to four rows of bunch plantings can be added. In this way, the selection of single plants can be continued and the manifestations of each plant line under bunch planting conditions can be easily observed and identified and the condition for selection is close to that in large field production. This raises the accuracy of selection.

Characteristics of many plant lines will have stabilized in the F_5 to F_6 generations continuously selected from single plants in the hybridization and combination of ordinary varieties, but in plant lines obtained from the hybridization and combination of distantly related parents, the characteristics generally stabilize in later generations. The indicator of stable characteristics is a uniform manifestation of the characteristics of the plants within the plant line. All superior and stable plant lines satisfying the goals of the breeding and cultivation can be threshed without distinguishing each individual plant to become a fixed new line and these can be placed for identification testing of new lines the following year. The plant lines which have not shown extraordinary performance but whose characteristics have stabilized can be eliminated. Plant lines which still manifest separation in extremely late generations should be screened to continue to select only the few single plants which have shown special superiority and the rest should be eliminated at appropriate times.

2) The Method of Mixed Selection

The method of mixed selection is simple and easily implemented. Therefore it is frequently used in breeding and cultivation of hybrids. The method of mixed selection is based on the fact that many characteristics are not clearly manifested in the selection of early generation hybrids. Therefore continuous selection of single plants before the F_5 generation is not as rigorous as in the method of selection by lineage. The method of mixed selection involves planting of each hybrid group in a small area and a mixed selection among the groups is made at time of maturation. To avoid missing superior single plants, more plants are planted in each group, generally over 5,000 plants. Since only a small amount of seeds are selected and harvested from each plant in mixed selection, plants of the F_2 to F_4 generations can be directly and densely sown, single plants can be planted very densely or they can be planted in bunches to reduce the planting area of the early generations of plants. Preliminary selection of plants with strongly inheritable characteristics such as growth period, plant type and resistance to disease should be made among the F_2 to F_4 generations according to the goals of breeding and cultivation and those plants not satisfying the goals of selection should be eliminated. Good plants should be mixed and harvested so that these characteristics of the mixed colony will be more uniform in the earlier generations. In mixing and selecting, the groups showing extremely poor performance should be eliminated at appropriate times. Generally, the characteristics of most of the plants of the later hybrid generations will have stabilized in the fifth generation and selection of single plants can be made. Thus, colonies of each group of F_5 plants must be planted single at ordinary row and plant distances. In making selections in the field, each single plant must be selected according to whether its general characteristics are good or poor but the number of single plants must be appropriately numerous. Plants of F_6 should be compared according to the lines planted and the plant lines showing superior and stable characteristics should be selected from among them for next year's identification tests of fixed new lines.

The advantage of the method of mixed selection is it reduces the planting area of the early generations and the amount of work. It can also fully retain the rich hereditary bases of each selected group and the variant content. The shortcoming of the method is that the accuracy of selection during the early generations is poor and the selection is not systematic, thus some superior combinations or plant lines cannot be determined early. The time for selective breeding using this method is also longer than that required by the method of selection by lineage. When the mixed colony is planted extremely densely to reduce the planting area, the growth and development of early maturing or short stemmed type plants will often be visibly suppressed by the tall stemmed and late maturing varieties. Some will even be eliminated by natural selection. Because each of the two methods of mixed selection and selection by lineage has its own advantages and shortcomings, appropriate use of the two separately or in combination should be determined by actual application and their use should be versatile. It is not necessary to insist on adhering to any particular method.

3.) Breeding and Cultivation by Radiation

Breeding and cultivation by radiation is the use of γ (gamma), χ (X-ray), β (beta) rays and neutron streams and such high energy ionic rays to treat paddy rice seeds or other organs of the paddy rice plant to bring about a mutation in the hereditary substance and then to select new varieties among the mutant individuals. For example, early rice Aifu No 9, Fuyu No 1, Fuzao No 2, geng rice Xiongyue 613, Jinfu No 1 are varieties bred by this method.

The source of radiation of such ionic rays as γ rays are produced by radioactive isotope cobalt^{60} or cesium^{137}, β rays are produced by radioactive isotope phosphorus^{32} or sulfur^{35}, and X rays are produced by the X ray machine. At present, the most frequently used are γ rays and X rays.

The use of various rays to irradiate living beings will always cause a certain degree of damage. The more the subject is subjected to exposure, and the higher the dosage of such irradiation, the more severe the degree of damage to the living being. The methods of irradiation include placing the radioactive source near the subject or placing the X ray machine in front of the subject and using solutions of isotope phosphorus^{32} and sulfur^{35} to soak the seeds or injecting such solutions into the body of the subject. All of these methods require specialized equipment and facilities for conducting such work. In general, only one part of the hereditary substance or individual cells of the living bodies irradiated by ionic rays mutates and these mutations are mostly recessive. Therefore, the growth plants after irradiation exist in an embedded state and will manifest themselves by separation only in the second generation. Thus generally selections cannot be made during the first generation when breeding and cultivating plants by radiation. The key generation for selection is in the second generation. The procedures for breeding and cultivation by radiation are as follows:

(1) Selection of the Primary Material

The characteristics of breeding and cultivation by radiation is that the basic characteristics of the original varieties can remain relatively unchanged while individual characteristics can be clearly changed. Therefore the method of breeding and cultivation by radiation is mostly used to improve certain shortcomings of an original variety. In general, local varieties or varieties from other localities with superior overall characteristics are generally used as primary material. They are subjected to irradiation and varient single plants which are improvement of plants of the original variety are intentionally selected. These are identified, compared and selected as new varieties. Primary material for breeding and cultivation by radiation can also include later generations of hybrids still in the stage of separation or hopeful new lines which have not stabilized.

(2) Irradiation

Irradiation will damage the living being. Over exposure will cause death. Insufficient exposure will not affect the living being and will not produce mutants. The amount of irradiation is called the dosage expressed in roentgens. Practical experience shows the most appropirate dosage of irradiation is a 40 percent or 50 percent lethal dose. This dosage will not cause death of too much of the irradiated material and will bring about a higher percentage of mutation. The 40 percent lethal doses for different growth stages of paddy rice are:

Dry Seed	20,000 - 35,000 roentgens
Germinating seed	3,000 - 5,000 roentgens
Seedling	4,000 - 6,000 roentgens
Young panicle differentiation stage	2,000 - 3,000 roentgens

(3) First Generation Plants

The first generation of irradiated plants is designated by M_1. M_1 plants generally germinate slowly, their percentage of germination is low, about 40 percent to 50 percent of the seeds do not germinate or cannot become sprouts. Resistance to adversity of the M_1 plants is also visibly weak and therefore management of cultivation in the seed beds or in the large fields must be intensified. M_1 plants contain or possess embedded mutant substances or parts which are mostly recessive. Mutant parts in the panicles of the main stem are more than those in the panicles of the tillers. Therefore it is best to plant single plants densely in transplanting to facilitate selecting main panicles. At harvesting time, the main panicles of each plant is harvested and each individual panicle is stored for panicle row sowing for the second generation (M_2). Several grains could also be taken at random from each main panicle and mixed or all of the panicles could be mixed as the mixed sowing material for the M_2 generation.

(4) Selective Breeding of the Second Generation and Later Generations

The second generation (M_2) is the key generation in breeding and cultivation by radiation. This is because the mutant material in the plants of the M_1 generation will separate and manifest itself in the M_2 generation. This is the basis for selecting new types and successful breeding of new varieties. M_2 plants can be directly sown or transplanted. The single panicles of M_1 are gathered and one panicle per row is sown and planted. The mixed seeds of plants of the M_1 generation can be sown and planted in one area. Each must be planted singly to make selecting the plants easy and the contrast variety and the original variety must be appropriately interplanted. Then they must be carefully observed and single mutant plants of value are selected.

Plants of the third generation (M_3) are sown and planted according to plant lines and the contrast variety and original variety must be appropriately interplanted singly. Most of the plant lines in M_3 have already manifested uniform stability. Those that manifest superiority can be harvested without distinction for line identification of the M_4 generation, comparison with lines of M_5 or demonstrative propagation. Single superior plants can be continuously selected from among those plant lines of M_3 that are still separating.

Minute variations which are not easily detected often exist in the M_2 and M_3 generations of irradiated hybrids. Sometimes special superior types will only emerge in the M_4 and M_5 generations. Therefore plants of the M_2 and M_3 generations can be mixed and planted in bunches to increase the number of plants in the colony and reduce oversight in the selections. The method of mixed selection described in the previous section can be taken as reference of mixing and planting in bunches of plants of these generations.

4. Utilization of Heterosis of Male Sterility

The first generation hybrids generally possess an unusually strong growth and high yield which have been widely utilized in the cultivation of corn. Corn is a dioecious plant. A large amount of hybrid seeds can be made artificially by removing the tassels from the female plant and pollinating them with the pollen of the male plant. Paddy rice is a monoecious and self pollinating crop. It is not suitable to artificially emasculate it and produce large amounts of hybrid seeds because it would produce fewer seeds, be slower, poorer and more costly. Therefore, simpler ways need to be sought, i.e., the use of male sterile lines as females to produce hybrid seeds. This method has already been popularized and applied in treating sorghum and corn. The utilization of male sterile heterosis is currently under intensive study and developments are rapid.

Utilization of male sterile heterosis of paddy rice generally involves the combination of male sterile lines, male sterile-free lines and male sterile restorer lines.

(1) The Three Lines and the Hereditary Characteristics of Combinations of the Three Lines

1) The Male Sterile Line of Paddy Rice (abbreviated as the sterile line)

Every spikelet of the paddy rice plant contains both the pistil and the stamen. At flowering time, the pollen of the stamen falls upon the stigma of the pistil, and after self pollination, seeds are produced. In each of the small panicle flowers of the male sterile plants, the pistil is normal but the pollen inside the stamen does not develop or has developed incompletely, is absent or no normal pollen is present. Thus self pollination does not bear fruit. Male sterility of the sterile line is controlled by the sterile genes and can be inherited stably to later generations. This sterile gene exists inside the cell nucleus and the cytoplasm as recessive genes antithetical to the fertile genes. They are illustrated in Figure 15.

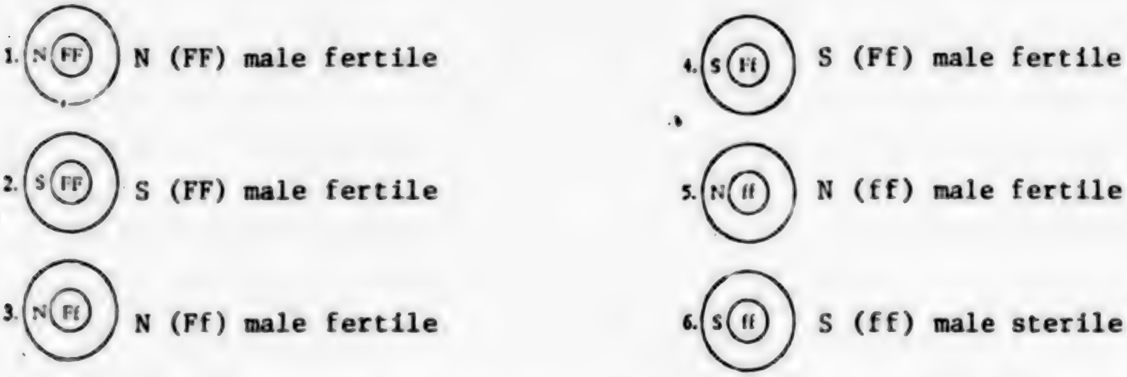


Figure 15. The genetic types of male fertility and male sterility. The large circle represents the cell and the small circle represents the nucleus. The letters inside the large circle represents the gene in the cytoplasm. Letters inside the small circle represents the genes inside the nucleus. N and F represent fertile genes, S and f represent sterile genes. N and F are dominant to S and f, ans S and f are recessive to N and F.

The genetic type of the male sterile line is represented by the sixth type S(ff).

2) Male Sterile Free Line (abbreviated the sterile free line)

The various characteristics of the male sterile free line are basically the same as those of the sterile line like a "twin." The difference is that the pistil and the stamen of the sterile free line are normal and when its pollen pollinates a sterile line, the plants grown from seeds of this sterile line are still male sterile and thus the male sterile line can be retained generation after generation. The genetic type of the sterile free line must be the fifth type N(ff) illustrated above.

3) Male Sterile Restorer Line (abbreviated the restorer line)

To produce a sterile line of hybrid paddy rice with visible superiority and yield which can be increased, there must be a restorer line with strong restoring and combining abilities. When the pollen of a superior restorer line pollinates a sterile line, the sterile line can fruit normally. When the hybrid seeds produced by the sterile line are planted, the plants thus grown have normal pollen and can self pollinate and fruit normally, and have visibly superior growth and can produce increased yields. The characteristics of the restorer line are entirely different from those of the sterile line. Thus its fertile genes must be of the first type N(FF) or the second type S(FF) as illustrated in Figure 15.

Heredity of groupings among the three lines are illustrated in Figures 16 and 17.

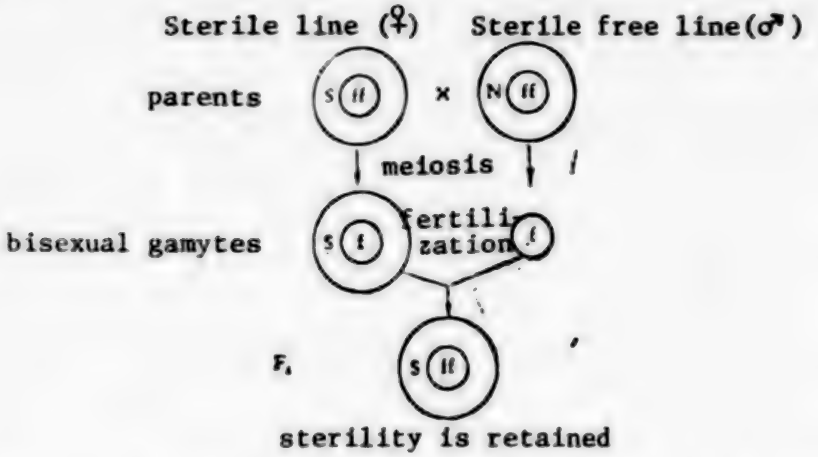


Figure 16. Heredity of the later generations of a cross between the sterile line and the sterile-free line

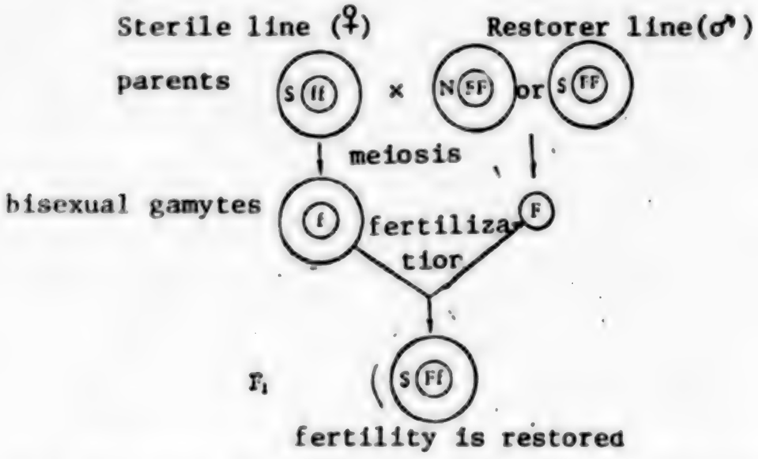


Figure 17. Heredity of later generations of a cross between a sterile line and a restorer line.

(2) Selective Breeding of the Three Lines

Selective breeding of the three lines is more complex and only a brief introduction is presented here.

1) Selective Breeding of the Sterile Line and the Sterile Free Line

To change a self pollinating fertile paddy rice plant to a self pollinating sterile paddy rice plant, the genes of the cytoplasm must be S while the genes of the nucleus must be ff. The plant's sterile free line must have N genes in the cytoplasm while the genes of the nucleus must be ff. The methods of selective breeding of sterile lines are also by hybridization, induction of mutation by radiation or selection of natural mutant types. The more frequently used method is hybridization of wild rice and cultivated rice or hybridization of xian and geng rice. When hybridizing distant varieties, the greater difference between the hereditary materials of the parents easily causes incoordination within the cells of the hybrids. After continuous back crosses and selection it is generally possible to form hereditary combinations of the cytoplasm of the female variety with the nuclei of the male variety and stable self pollinating sterile lines can be selectively bred.

Hybridization of a wild rice with a cultivated rice is used here as an example. Ordinarily, the wild rice is used as the female (mainly to use the genes in its cytoplasm) and a cultivated variety is used as the male (to induce the genes of the nuclei of the cultivated variety into the hybrid) for hybridization. Then, single plants with a high degree of sterility and whose phenotype is like the cultivated variety are selected from the first generation (or second generation) hybrid for self pollination and for use as a female in the back cross with the cultivated variety. The procedure is then repeated many times to select an S(ff) genetic type self pollinating sterile line in the image of the cultivated variety. If the above process is successful, this recurrent variety used as the male must have a genetic type expressed as N(ff) and thus becomes the sterile free line of this sterile line. In addition, in the selective breeding of the sterile free line, there are other methods such as the method of test crossing of paired single plants which will not be discussed here.

In general, we can only see the external form of the parental material we select and cannot know beforehand whether the genetic type possesses N, S and FF or ff. This can only be known through hybridization. Therefore many experiments are required to select the appropriate parents and successfully breed the required lines.

2) Selective Breeding of the Restorer Line

The genetic type of the restorer line must be N(FF) or S(FF). At the same time, its cross with the sterile line will produce a first hybrid generation with a strong superior growth and increases in yield. Selective breeding of such ideal restorer lines must involve multifaceted test hybridization and selection. This means, the sterile line must be test crossed on pairs with more varieties and the variety possessing both a strong restorability and combining strength is then selected. This variety is the male sterile restorer line of paddy rice.

(3) Seed Propagation

After the three lines have been selectively bred, the hybrid seeds must still be propagated. The sterile line and the sterile free line head and flower at the same time and thus need to be sown at the same time and transplanted at the same time. The seeds produced by later sterile lines (pollinated by the pollen of the sterile free line) will yield sterile lines and seeds produced by self pollination of sterile lines will yield sterile free lines. The sterile line and restorer line used for the propagation of hybrid seeds may have different heading times and thus their sowing times must be appropriately adjusted and then transplanted at the same time so that the flowering periods will meet. In the propagation of the seeds of sterile lines and hybrid seeds, the fruiting percentages must be raised. The direction of the rows in the field should be perpendicular to the direction of the winds of the locality during the heading and flowering periods so that the winds can help pollination. Also at the time of flowering, a thin rope can be used to pull at the rice panicles or a bamboo pole can be used to beat the rice panicles every 10 to 15 minutes to artificially help pollination. When hybrid seeds are used in large field production, they manifest heterosis and their growth is prosperous, therefore the number of plants transplanted per mu can be less than that of ordinary varieties while increased yield can still be obtained and the amount of seeds used is more economical.

5. Breeding and Cultivation of Monoploids and Multiploids

Paddy rice is a diploid plant. It has 12 pairs or 24 chromosomes ($2n = 24$). Monoploid breeding and cultivation is to cultivate the monoploid tissue into a monoploid plant ($n = 12$) and then the chromosomes are allowed to multiply and thus breeding new diploid varieties. Breeding and cultivation of multiploids is to allow the chromosomes of the original diploid variety to multiply to breed new tetraploid ($4n = 48$) varieties.

In cultivating monoploid plants, the best material is pollen. This is because each pollen grain is a cell with only a set of chromosomes after meiosis. Two days before heading, the anther is taken out and planted in a specially prepared base for cultivation. After 3 to 4 weeks, healing tissues will have grown from it. The healing tissues are then transplanted in another specially prepared base for cultivation to induce differentiation into seedlings. The monoploid seedlings thus produced are transplanted again for healthy growth. When a well developed root system emerges, the seedling is then transplanted in a pot for cultivation.

Monoploid plants have only one set of chromosomes and cannot undergo meiosis. Therefore they cannot fruit. They must multiple to become a diploid which are pure lines resulting from the combination of the same substance. Generally speaking, whether it is the first generation of a single cross or the first generation of a multiple cross or a cross between distant varieties, when the pollen is cultivated into a monoploid plant and when the chromosomes of the monoploid plant multiply, the plant will become a stable pure line without separating further. Therefore monoploid breeding and cultivation are an especially effective method of overcoming separation in hybrids and of shortening the periods of breeding and cultivation of hybrids. Because of the low frequency of formation of monoploid seedlings and the complex procedures, this method is not being applied in breeding and cultivation of paddy rice widely enough.

The most effective method of multiplying a monoploid plant to become a normal diploid plant is to treat the seedling with colchicine solution. The monoploid seedling at a growth period prior to the young panicle differentiation stage is uprooted from the cultivation pot, cleaned, and planted in a 0.05 percent solution of colchicine for 8 to 12 days. Then it is replanted in the cultivation pot. When it heads and fruits, a portion of the grains are large and full. These are diploid grains whose number of chromosomes have doubled. These full seeds are harvested from the plants separately for next year's plant line identification and comparison and selection of new and superior varieties. In actuality, during the course of cultivating the pollen, plants that have doubled and restored themselves as diploid plants by natural means without undergoing any artificial treatment often emerge.

The working process of producing multiploid plants is exactly the same as the working process of doubling the monoploid. Ordinary diploid paddy rice is treated in a solution of colchicine to obtain a tetraploid type of the same origin possessing such characteristics as thick stem, dark lead color and a thousand grain weight nearly double that of the original variety.

V. Introduction of Paddy Rice

Introduction of paddy rice refers to the introduction of new paddy rice varieties from other localities into a region for planting and cultivation. Direct use is to hasten propagation and popularization of superior varieties suitable for cultivation in the locality by conducting experiments on introducing other varieties. Indirect use is to introduce varieties with some superior characteristics although the varieties cannot adapt to the natural environment and conditions of cultivation of the locality as primary material for selective breeding and cultivation.

After the founding of the nation, introduction work developed greatly and achieved great results under the guidance of the proletarian revolutionary line of Chairman Mao. For example, Aijiaonante, Zhenzhuai and Nongken 58 all produced remarkably increased yields after being introduced into various localities. At the same time, the ceaseless development in the promotion of production was realized by introducing varieties as material for breeding and cultivation, selective breeding of many new superior varieties adapted to the needs of different regions and different planting systems.

Practice proves that introduction work is simple and easily implemented. It saves labor and expense, yields quick results and is advantageous for launching a mass movement. This method can hasten popularization of superior varieties in a short time and is a path to achieve greater, faster, better and more economical results in providing new varieties for production as well as an effective measure to solve the urgent need for superior varieties in production.

Although there are many successes in introduction, there are also some failures. The reasons for the failures are mostly because of an insufficient understanding of the characteristics of the varieties or improper cultivation, since all paddy rice varieties are developed under certain definite environmental conditions and all have a definite scope of adaptability. To establish the work of introduction on a reliable foundation, the mutual relationship between the growth and development of paddy rice and external environmental conditions must be studied to effectively guide introduction work.

1. The Relationship Between the Growth and Development of Paddy Rice and External Environmental Conditions

Engels pointed out: "Life is the form of existence of proteins. The fundamental factor of this form of existence is the ceaseless metabolism between it and its surrounding external nature." Paddy rice is like all other living beings. Its growth and development cannot be separated for one second from environmental conditions. It needs to absorb such ecological factors as water, temperature, light, air and nutrients from the external environment. Temperature and sunlight are most closely related to the growth and development of paddy rice. The growth and development of paddy rice is explained in the following:

(1) Paddy Rice's Sensitivity to Light

Within the temperature range suitable for paddy rice to exist, short daylight (a shorter day time) can shorten the growth period and long daylight can lengthen the growth period. This characteristic change in the growth period due to different durations of sunlight is called sensitivity to light. Varieties of paddy rice whose growth period visibly shortens when daytime is short and visibly lengthens when daytime is long are strongly sensitive to light. Varieties whose growth period does not change visibly regardless of the length of duration of daylight are weakly sensitive to light. Why do paddy rice varieties react differently to different durations of sunlight? This is the result of different historical conditions that form the varieties. Among these conditions, the length of duration of sunlight is a major factor and is a condition under which paddy rice has been growing for a long time.

Rice originally grew in tropical regions where temperatures are high and days are short. The basic type of rice is late rice which is strongly sensitive to light and requires short sunlight conditions for its panicles to differentiate and develop. Later, changes in the season of cultivation and planting further north at high latitudes and high elevations acclimatized it under longer daylight conditions for a long time and by natural selection and artificial selection, varient types with weak sensitivity to light emerged.

How does the length of the duration of sunlight change in nature? We know that except for the Equatorial region, the duration of sunlight at other places during a year changes. The duration of sunlight is long in summer and short in winter. This change varies at different latitudes. The higher the latitude the greater the change and the lower the latitude the smaller the change. For example, in our nation's northern Heilongjiang Province, the longest duration of sunshine in summer is 16.21 hours, the shortest duration of sunshine in winter is 8.05 hours. The durations of sunshine in the two seasons differ by 8.16 hours. In Hainan Island in the south, the longest duration of sunshine in summer is 13.21 hours and the shortest duration of sunshine in winter is 10.56 hours, a difference of 2.45 hours. Therefore, in our nation, paddy rice grown in regions along the same latitude and planted at different times is exposed to different durations of sunshine, early season rice grows under longer sunshine durations and late season rice grows under shorter sunshine durations. At different latitudes, the sunshine durations during the growth seasons of paddy rice are longer at higher latitudes and shorter at lower latitudes.

Cultivating paddy rice in different seasons in one region means paddy rice has to grow and develop under different durations of sunshine, and after a long period of exposure, its particular sensitivity to light is formed. For example, early rice of southern China has always been sown in February or March and has always matured in June or July. Late rice has always been sown in May or June and has always matured in October or November. This means early rice has for a long period been growing and developing under long durations of sunshine or lengthening durations of sunshine. Late rice has been growing and developing under shorter durations of sunshine or shortening durations of sunshine. Under these historical conditions, adapting to different durations of sunshine for a long period results in the formation of late rice's sensitive reaction to the duration of sunshine or a strong sensitivity to light and of early rice's less sensitive reaction to the duration of sunshine or a weak sensitivity to light. The season for growth of paddy rice in northern China, the northeast and the northwest is short and the difference between the sowing time and heading time at the same locality is not great. Thus the difference among the reactions of the varieties in these regions towards the length of duration of sunshine is not great. Among the paddy rice varieties of the same region but of different latitudes, varieties produced at high elevations are less sensitive to the length of duration of sunshine than varieties of lower elevations, and their demand for a short sunshine duration is not exact. This is related to the fact that the growth season for paddy rice at higher elevations is shorter.

The further north the origin of a variety, the weaker its reaction to the length of the duration of sunshine. This is because of two reasons: The first is that the higher the latitude the longer the duration of sunshine in summer. Therefore the varieties of higher latitudes of the original locality must adapt to longer sunshine durations. The second reason is the higher the latitude, the lower the temperature and the shorter the growth season for paddy rice. Thus the paddy rice must mature earlier so that paddy rice can grow and develop under longer sunshine conditions, otherwise it will not be able to exist. Therefore, varieties from higher latitudes at the original place of production react less sensitively to sunshine and require less exact conditions of short sunshine durations. Varieties from lower latitudes at the original place of production react more sensitively to different sunshine durations and require more exact conditions of short sunshine durations.

(2) Paddy Rice's Sensitivity to Temperature

Paddy rice is a thermophilous crop. It requires temperatures above 12 degrees C for it to begin to grow and temperatures above 23 degrees C for it to head and flower normally. Within the temperature range suitable for paddy rice to exist, higher temperatures will shorten its growth period and low temperatures will lengthen its growth period. This characteristic change in the growth period due to variations in temperature is called the sensitivity to temperature. Among different types of varieties, the degrees of change in the growth period due to variations in temperature are different.

The length of the duration of sunshine affects only a certain stage of growth and development of paddy rice significantly while temperature affects paddy rice throughout the entire period of growth. From the time of sowing to the time of germination, the paddy rice is obviously only affected by temperature. Within a definite temperature range, the speed of growth changes as temperature changes. From the time of germination to the stage of differentiation of the meristems of the stem, temperature and sunshine affect the rice plant simultaneously. Varieties that are strongly sensitive to light are mainly affected by the duration of day. Varieties that are less sensitive to light are mainly affected by temperature. From the time of young panicle differentiation to the maturation stage, temperature exerts the major effect and the duration of day exerts less effect.

(3) Basic Vegetative Growth of Paddy Rice

The life of paddy rice can be divided into the vegetative growth stage and the reproductive growth stage. The period before young panicles begin to differentiate is the vegetative growth stage. The period after young panicle differentiation is the reproductive growth stage. The difference in the lengths of the growth periods of paddy rice varieties is mainly due to the difference in the duration of the vegetative growth stages. The length of the reproduction growth period does not change greatly. The length of the vegetative growth period of a variety is determined by the basic vegetative growth period and the perishable vegetative growth period. The period which perishes as a result of high temperatures and short daytime is called the perishable vegetative growth period. The period which is not affected by length of day and temperature changes and which does not perish and which is also the number of days of vegetative growth absolutely necessary for the plant to enter into reproductive growth is called the basic vegetative growth period. The characteristic of basic vegetative growth not being affected by high temperatures and short days is called the property of basic vegetative growth. Varieties with a smaller property of basic vegetative growth easily shortens or lengthens the vegetative growth period because of changes in temperature and light. The property of basic vegetative growth can be obtained by the use of the following formula:

Property of Basic Vegetative Growth (%) =

$$\frac{\text{Vegetative growth period - perishable vegetative growth period}}{\text{Vegetative growth period}} \times 100$$

Studies show that the length of perishable vegetative growth periods of early, intermediate and late rice varieties of one locality affected by both high temperatures and short days is different. In general, varieties that are less sensitive to light have shorter perishable vegetative growth periods and varieties that are strongly sensitive to light have longer perishable vegetative growth periods.

Late rice is a type of rice that is strongly sensitive to light. Short days exert a greater affect upon the perishable vegetative growth period than high temperatures. Early rice is weakly sensitive to light. High temperatures exert a visibly greater affect upon the perishable vegetative growth period than short days.

2. Changes in Characteristics After Introduction

Practice in introducing plants to various localities show that introduction of plants to different latitudes and elevations causes changes in the economic characteristics and the growth periods. The changes follow a definite pattern.

(1) Introduction of Plants From Regions at Low Latitudes to Regions at High Latitudes (Moving Northern Varieties South)

In the high latitude regions of the northeast and north China, temperatures are low, the growth season is short and thus northern varieties generally have shorter growth periods. Since they have been growing under longer sunshine conditions for a long time, they are less sensitive to light. After they are introduced to the south and growing under higher temperatures, their growth period shortens. The further south they are introduced and the higher the temperatures during their growth period, the shorter their growth period becomes. As continuous late rice crops growing in high temperatures seasons, the growth period shortens even more. At the same latitude, introducing plants from lower elevations to higher elevations also brings about similar manifestations. As the growth period shortens, other economic characteristics also degenerate. This is mainly because shortening of the vegetative growth period reduces the number of leaves, shortens the tillering period, correspondingly reduces the amount of nutrients accumulated in the plant, thus the plants become short, the number of grains per panicle lessens. In addition, the difference in temperatures in the daytime and at night is less than that of the original place of production, the plants expend more nutrients and thus the degree of filling of the grains is affected, causing the thousand grain weight to drop and the quality of the rice to become poorer. The degree of degeneration of economic characteristics and the shortening of the growth periods are different for different varieties with different growth periods. In general, the degree of shortening of the growth period and the degeneration of economic characteristics of varieties with a long growth period are less severe. The degree of shortening of the growth period and degeneration of economic characteristics of varieties with a short growth period are more severe. Therefore in introducing plants from low latitude regions to high latitude regions, intermediate and late maturing varieties with longer growth periods are most suitable. Varieties from regions of high latitude and high elevations possess stronger tolerance to cold. As early rice, they should be sown early to extend their vegetative growth period. This will help raise the yield. As late rice, they should be sown late. Their seedling age should be kept young (short) and they should be transplanted early. They should be fertilized early and managed early to stimulate early germination and fast growth. Higher yields can thus be obtained.

(2) Introducing Plants From High Latitude Regions to Low Latitude Regions (Moving Southern Varieties North)

In low latitude regions, the temperature is high and the duration of sunshine is short. After introducing paddy rice to the north, the growth period generally is prolonged because the temperatures during the period of growth is lower and the duration of sunshine is longer. The economic characteristics also increase correspondingly. When introducing plants from high latitude regions to low latitude regions, the major problem to be considered is that after the growth period of the variety is prolonged, whether it can match the growth season of the locality and the demands of the planting system of the locality. Late xian of southern China will not head when the length of day is over 13 hours. The late rice of the Changjiang River valley will not head when the length of day is over 14 hours. The late rice of southern China cannot be introduced to the Changjiang River valley and the late rice of the Changjiang River valley cannot be introduced to the north. This is because when the short day season required by the late rice comes in the north, the temperatures have already dropped to a low at which point the plants are unable to head and fruit. Let us take an early xian of southern China as an example, Guangdong Province's early maturing early xian guangluai No 4. When introduced to the Changjiang River valley for planting, its growth period prolonged, the plants became taller, the number of grains per panicle increased, although the number of semi-empty grains increased and the thousand grain weight dropped, the yield was still higher than that at the original place of production. The reason for the higher percentage of semi-filled grains is because of the lower temperatures during the heading period or more rain during the flowering period. A lower thousand grain weight is due to the sudden increase in temperatures during the latter period of growth. High temperatures and depressing heat reduce the weight of the grains. The growth period of intermediate and late maturing early xian varieties of Guangdong Province introduced into the Changjiang River valley as continuous cropping early rice is too long and generally they can only be planted as single season intermediate rice or continuous late rice crop.

3. Problems To Be Taken Into Consideration in Introduction Work

(1) Survey and Research Work Must Be Done Well

The work of introducing plants to other regions should start out from actual production in the original region and should be implemented according to plan to achieve a certain goal. In introducing plants, there must be a profound understanding of the natural conditions and planting systems of the original place of production, and the history of selective breeding and adaptability of the introduced varieties. These should be analyzed and compared with the actual conditions of production of the locality to forecast possible happenings so as to prevent blindly introducing plants for planting. First of all, the type and growth period of the variety must be studied to see if they can adapt to the demands of the planting system of the locality. If they cannot be matched, then however superior the other characteristics of the variety are, it cannot be used directly. The second point to consider is the characteristics of stable and high yield and superior quality. Only in this way can the effectiveness of introduction be raised and the goal of exerting half the effort to achieve full success is possible.

(2) Everything Must Be Subjected to Experiment

On the basis of surveys and study prior to doing well the work of introducing palnts, we must experiment and identify the introduced varieties to further understand their adaptability and potential for increased yield. Then the varieties that have truly performed in a superior way can be popularized step by step according to the dictates of local circumstances. Generally, experimenting with introduction of plants involves two steps:

The first step is to introduce a small amount at first. Many different varieties can be included but the number of seeds of each variety should be less. Then, comparative experiments of the introduced variety and the locally popular superior varieties must be conducted.

The second step is to test plant the varieties that have performed in a superior way in the test introduction over a larger area as a demonstration. The members of the leadership, experienced poor and lower-middle peasants and technical personnel must perform critical selection and identification to determine the value for popularization. At the same time experiments in the sowing and transplanting times, planting density and application of fertilizers should also be conducted together to study the most suitable planting and cultivation techniques.

(3) Quarantine Work Must Be Done Well

In introducing plants, special emphasis must be placed on quarantine of disease and insect pest damage. A system of quarantine of diseases and insects and inspection of seeds must be conscientiously implemented to strictly prevent communication of diseases and propagation of insects. Seeds that are under quarantine must never be introduced. If diseases and insects that are under quarantine are discovered in introduced varieties, measures must be taken to control them or the introduced varieties must be burned and destroyed.

(4) Introduction Work Must Be Coordinated With Selection

In the course of experimental introduction, propagation and cultivation, continuous selections must be made to preserve the purity of the original variety and the typical type of the variety. This is because when a variety is introduced to another locality, various variants will necessarily be produced and thus the work of selecting the superior and eliminating the poor must be conscientiously carried out.

VI. Techniques of Propagating and Cultivating Superior Varieties of Paddy Rice

The unprecedented Proletarian Cultural Revolution greatly pushed forward the profound development of the mass movement of "Learning from Dazhai in Agriculture." Every locality conscientiously implemented the policy of "four self and one help" (self selection, self propagation, self reserves, self use, helping by using necessary agents for adjustment) in the work of seed propagation based on the spirit of self reliance. Great achievements have been realized and many progressive types have emerged.

The content of propagation and cultivation of superior varieties, as the words indicate, involves "propagation" and "cultivation." This means two things: one is the problem of how to produce superior seeds for use in production to achieve greater, better, faster and more economical results; and the second is the problem of how to raise the superiority of the superior varieties and prevent degeneration of superior varieties. The planting area of a superior variety will be affected if a production unit does not have a sufficient amount of seeds of that superior variety. At the same time, having a superior variety and sufficient amount of seeds but neglecting the work of raising the superiority of the superior variety will allow the superior variety to degenerate and become impure within a short time. The purpose of increasing production by the superior variety will not be fully realized.

Therefore, whether the propagation and cultivation of superior varieties is done well or not directly dictates the speed and the effectiveness of the realization of the purpose of increasing production by the superior varieties.

1. Techniques and Method to Hasten Propagation of Seeds

A newly bred variety at the beginning often produces a small amount of seeds. To popularize a new variety as quickly as possible, measures must be taken to hasten propagation of seeds. The methods used in recent years by various localities generally include: planting of single plants sparsely, replanting in autumn (reverse spring planting), regenerative rice, propagation at different localities, and breaking off a portion of the seedlings and planting them. Some of these methods are used to increase the number of times of propagation. Other methods are used to raise the coefficient of propagation of seeds (i.e., ratio of the amount of seeds sown and the amount of seeds produced by a unit area). The common purpose of these methods is to make it possible for each seed to realize its utmost ability to propagate at the fastest rate possible so that a limited number of seeds can produce as many seeds as possible to satisfy the need for the development of production.

(1) Sparse Planting of Single Plants

Single seedlings are transplanted at approximately greater distances between rows and plants so that the plants will tiller more and produce more panicles. To achieve this goal, healthy seedlings must first be cultivated. At sowing time, they must be sown sparsely and management of the seed bed must be strengthened so that the seedlings will grow to be strong and healthy. Then, the large field must be managed finely and carefully, sidedressings must be applied early so that the plants will germinate early and quickly and the percentage of tillering will be raised. At the same time, applications of phosphorus and potassium fertilizers must be increased to reduce the percentage of empty and semi-filled grains and increase the weight of grains so that the seeds will develop well and the quality of the seeds will be raised.

(2) Replanting in Autumn (Reverse Spring Planting) Propagation in Different Localities and Regenerative Rice

In the regions south of the Changjiang in our nation, the method of replanting in autumn is often used to propagate the seeds of new varieties of early rice. The method is to sow the seeds harvested from early rice again, transplant the seedlings again and to perform the cultivation process again. When using this method, the growth period of the variety and characteristics of the weather of the locality must be thoroughly known. Then, the appropriate time for sowing and transplanting is determined and the fore crop and after crop are coordinated to prevent low temperatures during the latter part of autumn from hindering heading or fruiting after heading.

When a superior variety cannot be replanted in autumn at the locality and its seeds must be quickly propagated, then it can be brought to the southern regions of our nation for propagation at a different locality. The following points should be taken into consideration when conducting propagation of varieties at different localities: (1) The growth characteristics of the varieties to be propagated and the weather conditions of the other locality must be thoroughly understood so that the most appropriate time for sowing and transplanting can be determined. (2) The seeds to be propagated at the other locality must be shipped there before the sowing season to avoid a waste of effort because of a delay and missing the season. (3) When the seeds are taken to Hainan Island for winter cultivation, care must be taken to prevent the rice plants from heading in early spring in low temperatures and thus affecting the fruiting percentage.

The regenerative ability of paddy rice is strong and the use of regenerative rice is also a method to increase the amount of propagation of seeds. At time of the first season's harvest, the field should be kept moist and the taller stubble should be left. After the harvest, irrigation water must not flood the rice stubble. Sidedressings of fertilizers must be heavily applied immediately and the field must be weeded carefully to stimulate the tillers to grow again.

(3) Breaking Off the Seedlings and Replanting Them

This method is to break off the tillered seedlings during the tillering stage of paddy rice and replanting them so that the tillered seedlings will tiller again into panicles. Because tillered seedlings that have been broken off will have a later maturation time, the time for breaking off the seedlings must be as early as possible. The seedlings broken off must have roots, they must be planted in time and they must be managed carefully. To assure that the seedlings are broken off early, the parental plant must be sown early and its seedling must be planted early. Management of the parental plant must be initiated early and it must be taken care of frequently. Application of fertilizers must be increased so that it will grow early, and tillers will grow fast for use in time. In breaking off tillered seedlings of late rice for propagation, the season must be grasped tightly to avoid damage by low temperatures during the later growth period.

The several methods mentioned above can be used in a versatile way according to actual conditions of the locality but the methods must not be used blindly to avoid mistakes that will hinder the achievement of the goal of hastening propagation.

2. The Phenomenon of Degeneration of Superiority of Superior Varieties and Its Cause

Large scale production practices indicate that when a superior variety has been planted in one region for many years and seed selection and preservation have not been done conscientiously, the superiority of the superior variety will degenerate. Actual manifestations of such include, for example:

the ability of the superior variety to increase yield drops, the plant type becomes tall, the plants easily lodge, growth and maturation becomes nonuniform, shattering easily occurs, resistance to disease weakens, adaptability lessens, the shape of the panicle becomes small, the density of the grains become sparse, the husks thicken, the yield of rice lessens, the color of rice changes to red and the quality of the rice becomes poor. There are three main reasons why these phenomena of degeneration occur:

(1) Mechanical Mixing

Throughout the entire course of paddy rice production, artificial mixing or so-called mechanical mixing can occur at any one of the operational links such as soaking the seeds to hasten germination, sowing, transplanting, harvesting and threshing, drying the seeds, storage and transportation. After seeds have been mechanically mixed, the purity of the superior variety drops rapidly. This changes the relative uniformity among the individual plants in the colony of the superior variety and directly affects the full realization of the purpose of using the superior variety to increase yield.

(2) Effect of Natural Hybridization

Although paddy rice is a self pollinating crop, in general, there is still a 1 percent rate of natural hybridization. In some serious cases, the rate may reach 4 percent. If different varieties are mixed together due to mechanical mixing, or if different varieties are planted in neighboring fields, then natural hybridization easily occurs during heading time. After natural hybridization, the characteristics of later generations will separate and variant individual plants will emerge in the colony of the superior variety, causing degeneration of superiority.

(3) Effect of Natural Variations

All things are mobile, developing and changing. Paddy rice varieties are the same. They are changing all the time. Under the effect of such natural conditions as bad weather and bad soil and conditions of cultivation, the characteristics of paddy rice varieties often become poor and becomes another cause of degeneration of superior varieties.

In addition, some varieties are selectively bred by artificial hybridization. They have not been sufficiently stabilized when they were popularized and their characteristics continue to separate and thus their value of utilization in production has dropped. This should also be taken into consideration.

3. The Method and Techniques of Preventing Degeneration of Superior Varieties and Raising the Superiority of Superior Varieties

Change of a superior variety is manifested by the variations of individual plants in the colony. All things have duality. Changes of superior varieties are the same. In the individual variants, there are unfavorable changes and sometimes superior changes occur. Thus, in the course of preventing degeneration of superior varieties and raising the superiority of the superior varieties, we must constantly abandon individuals that have changed unfavorably and individuals of different varieties, retain the relative uniformity among the individuals in the colony of the superior variety, and effectively prevent degeneration of superior varieties. On the other hand, we can also ceaselessly make selections among superior varieties to continuously raise the superiority of the superior varieties. This is what is commonly known as raising the purity and revitalizing the healthy. There are two actual methods. One is to establish a seed plot system on a wide scale in production teams and production brigades. The other is the "three plots" method of revitalizing the healthy to be carried out by scientific research units, state-run farms for original (superior) seeds and well managed and well equipped production brigades. A comparison of the two shows that the former method is simple in procedure, requires a short time and yields quick results. The latter method takes a long time, requires high technology and the effects produced are more remarkable. Regardless of which method is used, as long as the work is done persistently, gradually, the goal of supplying high quality seeds for production every year can be reached. The methods are discussed in the following:

(1) The Seed Plot System

Seed plots are definite areas of land designated especially for the production of seed for use in production in large fields. The plots serving as seed plots must have good quality soil, their fertility must be even, the grounds must be relatively level, sunlight must be sufficient, drainage and irrigation must be easy and weeds must be few. It is best to plant the same variety of crops in fields neighboring the seed plots to avoid natural hybridization between varieties.

The actual method of establishing seed plots is to divide the seed plot into two parts, one part for planting single seeds and the other part for planting seeds in bunches. The plants (panicles) in the single plant seed plot should be selected singly and the superior single plants (panicles) selected be threshed in mixed fashion as seeds for planting in the single plant seed plot next year. The remaining part of the plot is thoroughly cleared of impure plants, plants of poor quality, grass and diseased plants. Then the seeds are harvested for planting in bunches next year in the seed plot. The seeds harvested from the seed plot planted in bunches are also thoroughly cleared of impure plants, plants of poor quality, grass and disease plants. The seeds are then harvested for planting in the large fields next year. Persisting in this work year after year will produce good results.

The size of the seed plots should be determined by the area of the large field using the seeds produced by the seed plots. If a certain production team plants 100 mu of Erjiuqing variety of rice, and 40 jin of seeds are retained per mu, a total of 4,000 jin of seeds would be required. If 600 jin of seeds are produced by the seed plots planted in bunches, then an area of 7 mu would be enough for the seed plot planted in bunches to satisfy

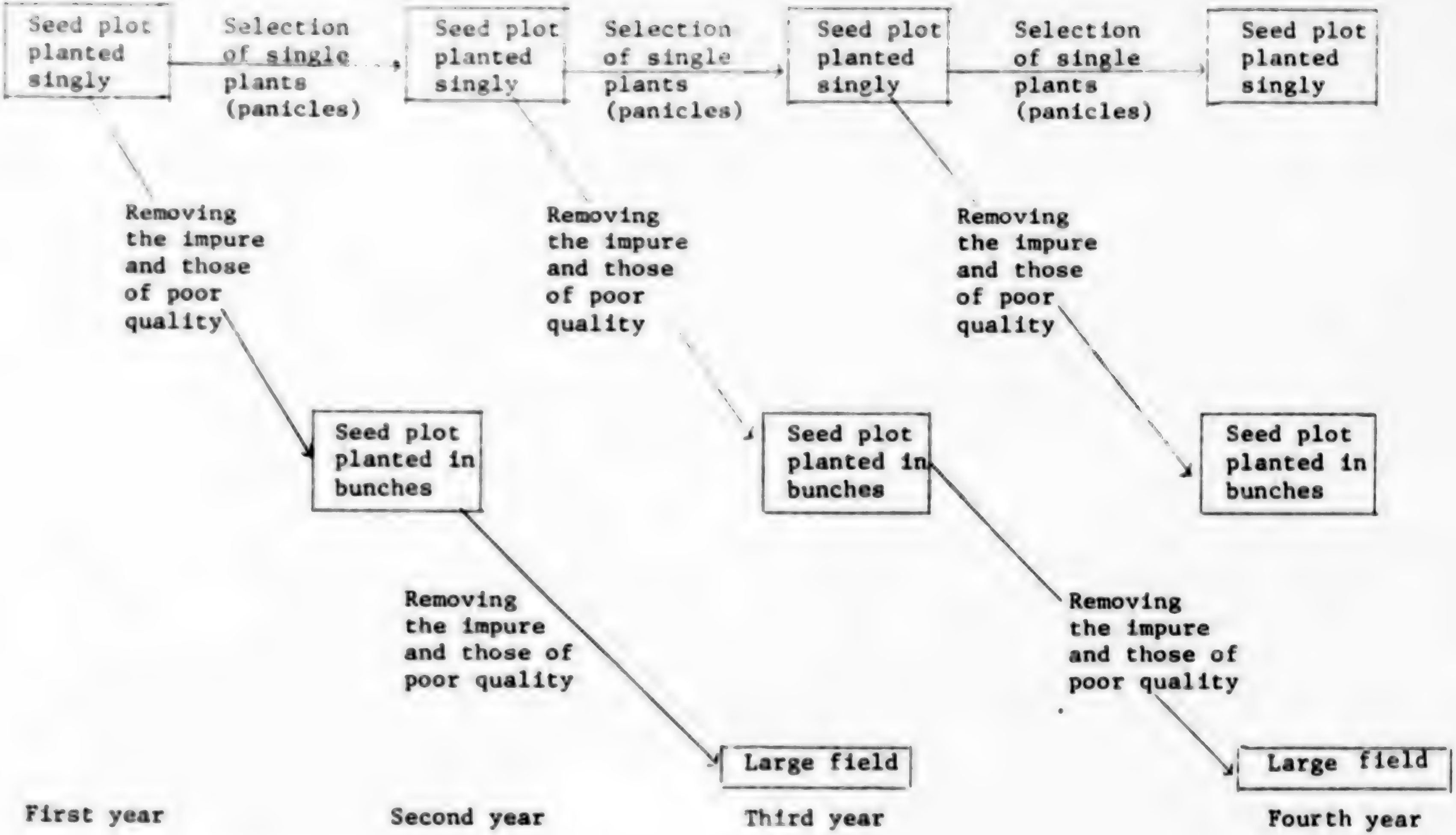

Seed plot planted singly
Selection of single plants (panicles)
Seed plot planted singly
Selection of single plants (panicles)
Seed plot planted singly
Selection of single plants (panicles)
Seed plot planted singly
Removing the impure and those of poor quality
Removing the impure and those of poor quality
Removing the impure and those of poor quality
Seed plot planted in bunches
Seed plot planted in bunches
Seed plot planted in bunches
Removing the impure and those of poor quality
Removing the impure and those of poor quality
Large field
Large field
First year
Second year
Third year
Fourth year

Figure 18. Illustration of the System of Seed Plots

the need. In the same way, if 40 jin of seeds are retained for each mu of the seed plot planted in bunches, a 7 mu seed plot planted in bunches requires 280 jin of seeds. If the yield of the seed plot planted singly is 500 jin of seeds then one sixth mu of land is sufficient for the area of the seed plot planted singly. The source of seed for the singly planted seed plot of one sixth mu can come from the seeds selected from the single plants (panicles) in the singly planted seed plot of the previous year or from the original seeds introduced from other localities. Generally, only 3 jin of seeds are sufficient. Summarizing the above method of calculation we obtain the following formula:

Area of the seed plot planted in bunches =

$$\frac{\text{area of large field x amount of seeds each mu of the large field uses}}{\text{yield per mu of the seed plot planted in bunches}}$$

Area of seed plot planted singly =

area of seed plot planted in bunches X

$$\frac{\text{X the amount of seeds each mu of seed plot planted in bunches uses}}{\text{yield per mu of the seed plot singly planted}}$$

The quality of the seeds propagated in the seed plots depends upon the quality of the selected single plants (panicles) and the thoroughness of removing impure plants, plants of poor quality, diseased plants and weeds. Therefore, care must be taken in the selection of single plants (panicles) and in removing impure plants, plants of poor quality, diseased plants and weeds.

(2) The "Three Plots" Method of Revitalizing the Healthy

The "three plots" method of revitalizing the heathy is to establish a plot for selection of seeds, a plot for plant lines and a plot for original varieties during the course of revitalizing the healthy plants. Actual procedures are illustrated as follows:

1) Plot for Selection of Seeds

Superior single plants (panicles) are taken from the fields of uniform and healthy plants of a certain variety, mixed and threshed as material for sowing in the plots for selection of seeds. Scientific research units or other original (superior) seed farms can also introduce superior seeds to establish the plots for selection of seeds. To provide even more opportunities to select superior single plants, it is best to purposely collect better quality seed of the same variety from original (superior) seed farms of different regions and from communes and production teams with an established foundation in the work of seed selection. These are mixed and then sown. Sowing in the seed bed should be sparse, management must be strengthened to cultivate healthy seedlings. Even, uniform and healthy seedlings are then selected and transplanted singly. A working aisle is left open at intervals of every 6 or 12 rows.

Selecting single plants is the key to the technique of establishing the plot for selection of seeds. Whether the selected single plants are superior and whether they are the type of the original variety directly affect the percentage of selection of later plant lines and the results of revitalizing the healthy plants of the variety. The fundamental principle of selecting single plants is: to select superior single plants with good surplus yields on the basis of the characteristics that typify the variety (the major characteristics representing that variety) so that the variety's characteristics of surplus yield and its typical characteristics can be combined. When the selection is made, the characteristics (superior qualities) of each variety must be grasped, their shortcomings overcome so as to restore, solidify and raise the superiority of the varieties.

Selection of single plants involves preliminary selection in the field and semi-final selection indoors. Preliminary selection in the field involves tagging or eliminating poor quality plants in the field when the characteristics of the varieties are most visibly manifested. For example, at tillering time such characteristics as the concentration of the stems, shape of the leaves, color, time of tillering and the amount of tillers and the growth trend can be used to eliminate poor quality plants and diseased plants. During the heading stage, the time of heading, uniformity of heading, plant height, size of the boot leaf and angle of the boot leaf can be used as indicators. During the maturation stage (mainly during the milky ripe stage), the shape of panicles, angle of the boot leaf, resistance to adverse conditions and color of ripeness can be used as indicators for selection. When selecting single plants, small pieces of bamboo or other tags can be used and the selection can be made according to the results obtained from separate observations made at different stages of growth. After maturing, the selected single plants are separately uprooted for semi-final selection indoors. Semi-final selection indoors is b sight based on the preliminary selection in the field. Such major characteristics as uniformity, fruiting percentage and fruiting at the base of panicles of the single plants chosen in the preliminary selection can be used to judge and eliminate single plants not meeting the requirements. Then the single plants selected from the semi-final selection are tested. The tests include such items as plant height, uniformity of height, length of panicles, number of grains per panicle, percentage of fruiting and thousand grain weight. According to the strength of each major item, a further selection is made by further eliminating those single plants not satisfying the demands. Finally, the single plants selected at the final selection must be threshed separately, stored individually, tagged and labeled and numbered for storage. The final selection must not be less than 50 plants.

2) Plot for Plant Lines

A field of even soil quality and fertility and possessing an above medium fertility should be chosen for the plot. Superior single plants selected the previous year are then planted in numerical order according to lines and compared. Cultivation management is done according to the characteristics of the varieties. Early rice should be planted in green manure fields.

Late rice should be planted in specially reserved seed beds. Stubble of rice plants must be removed when tilling, raking and weeding the fields and regenerative rice must be removed to prevent mixing of the varieties.

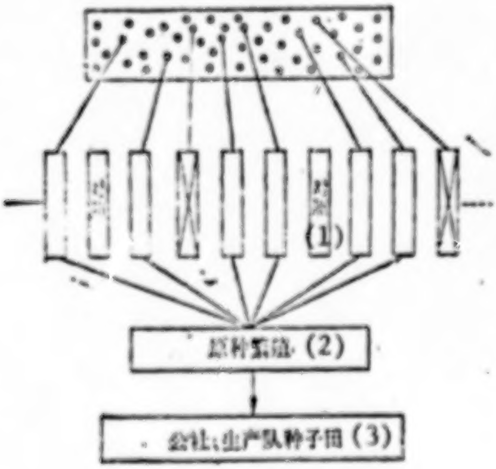
Field design of the plots for plant lines is to plant each plant line in one small area. The small area should be rectangular and all small areas must be uniform in area. The plants are transplanted singly and a contrast plant (using the same variety of plants of better quality but not revitalized and ordinarily used for planting in the large fields or a revitalized original variety) is planted at intervals of every 4 or 9 areas. A planting map for the fields is drawn and a notebook is prepared for field records. Transplanting and application of fertilizers in each small area should be as even and uniform as possible. Each farming activity must be completed within a day to reduce human error. Protective rows must be set up around the experimental fields. The contrast variety of plants is also planted in the protective rows. Within one zhang surrounding the plot lines, the same variety of plants should be planted, or varieties with a heading and flowering time different by 10 days or more. This will prevent natural hybridization which will affect the results of raising the purity and revitalizing the healthy.

During the tillering stage, heading stage and milky ripe stage, examination of the plant lines as to their typical characteristics and surplus yields should be continued. Throughout the entire examination process, special attention should be paid to the plant height, plant type, uniformity of heading and observation and recording of the growth period. All plant lines that deviate from the typical characteristics of the original variety and all plants affected by disease or insects, plants with nonuniform heading and tillering, or hybrid plants and plant lines that are still separating should all be recorded in time for elimination. If superior plant lines are discovered, they could be used as material for selective breeding of new varieties and kept for continued planting the following year for observation. A special person should be assigned to make field observations and records and the work should not be reassigned before the work is completed. After each plant line has matured, the leadership, poor- and lower-middle peasants and technical personnel should come together as a three way alliance to critically select the superior plant lines and eliminate those areas of plants that do not satisfy the requirements (The percentage of elimination is usually between 20 percent and 30 percent). Each line in the selected small area should be harvested separately, threshed and the yield measured. All small areas with a yield higher than the neighboring contrasts can be selected. The seeds of the plants of these small areas are then mixed for propagation in the original seed plots the following year. If because of limited conditions the yields of the areas cannot be separately measured, the plants from the selected small areas can be mixed and threshed directly as material for sowing in the original seed plot. The yield per mu should be calculated and compared to the average per mu yield from the contrast areas to determine the surplus yield.

3) Original Seed Plot

The original seeds produced from mixed threshing of the selected plant lines of the previous year can be propagated in the original seed plots of the local unit and can also be distributed to the agricultural departments of the locality for planned propagation by key production brigades. The original seed plots should be fields of good quality soil. Sowing must be timely. The field must be managed carefully. Application of fertilizers must be increased. Disease and insect pests must be prevented in time. Growth should be stimulated so that it will be uniform and healthy. The plants should have green stems and be yellow ripe so that pure, clean, healthy and strong original seeds can be obtained. "Purity" means that there are no seeds of different varieties, different crops and weeds. "Cleanliness" means there is basically no impurities and waste material. "Health" means the seeds are basically not diseased nor damaged by insects, and especially not carrying quarantined diseases or insects. "Strength" means the grains are full, the strength of germination is strong and the percentage of germination is high. Actual standards are uniformly established by concerned departments.

The "three plots" method of revitalizing the healthy seeds is illustrated in Figure 19.



Plot for selection of seeds (single plant selection) first year

Plant line plot (comparison of separate lines) second year

Original seed plot (mixed line propagation) third year

Fourth year

Figure 19. Illustration of the three plots method of revitalizing the healthy seeds

Key:
(1) contrast
(2) propagation of original seeds
(3) Seed plots of communes and production brigades

Appendix: Major Items of Selecting Single Plants in the Field and Testing the Seeds Indoors

1. Items of Selection in the Fields

(1) Concentration of stems

(2) Amount of tillers, time of tillering

(3) Strength of the growth trend

(4) Time of heading and uniformity of heading

The heading times of the selected single plants (plant lines) should basically occur on the same day. Uniformity of heading means the number of panicles headed within 8 to 10 days after planting of single plants or the number of panicles headed within 6 to 8 days after planting of several plants in bunches amounts to 80 percent or more of the total number of panicles.

(5) Uniform height of the plants

This refers to the uniformity of the distance between the tip of the main panicle and the tiller panicle on a single plant. Measuring from the neck node of the main panicle as the starting point, 80 percent or more of the neck node of the panicle should be within a length equivalent to the length of a fist.

(6) Resistance to adversity

This includes resistance to disease, lodging, cold, and also means that at maturity, the bottom of the rice plant is clear, the stem is green and the plant is yellow ripe and does not wither early.

2. Items of Testing of Seeds Indoors

(1) Plant height

(2) Uniformity of the height of plant

(3) Length of panicles

(4) The number of grains per panicle

(5) Density of the grains

(6) Fruiting percentage

(7) Thousand grain weight

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